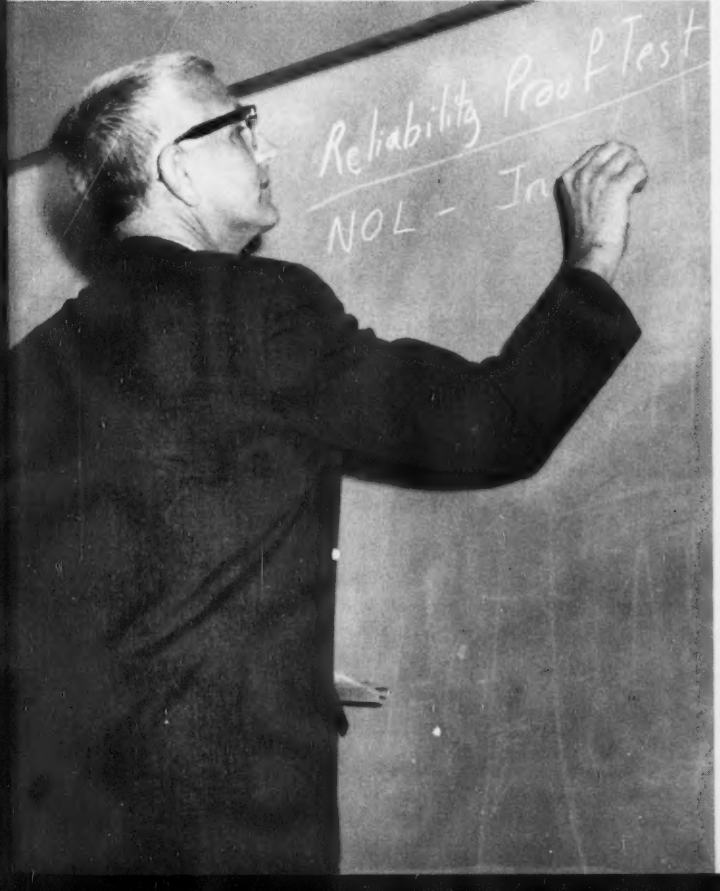
OCTOBER 1961

the JOURNAL of ENVIRONMENTAL SCIENCES

OFFICIAL PUBLICATION OF THE INSTITUTE OF ENVIRONMENTAL SCIENCES



A STUDY OF CONVECTIVE CURRENTS IN WATER

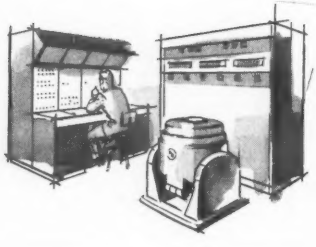
DISTURBING FORCES IN A ROTATING SPACE STATION

VIBRATION TESTING AND THE PERPETUATION OF MYSTERY

DR. LESLIE W. BALL LECTURES See Page 24

The important advances in environmental testing come from MB

New 5140MB power amplifier improves reliability in sine wave and complex motion testing



A pioneer and leader in the field of electrodynamic vibration systems, MB continually strives to improve the performance and reliability of vibration, shock and fatigue testing. The important advances in environmental testing come from MB.

MB Electronics has representatives in principal cities throughout the world.

The Model 5140MB Power Amplifier is designed to drive the Model (C210) 28,000 lb. force and Model (EL 10,000) 40,000 lb. force vibration exciters. Rated at 140,000 volt amperes output with plate dissipation of 240 kw, the amplifier offers the most conservative and reliable operation in the vibration testing field. It will readily handle all the adverse inductive and capacitive loading of the electrodynamic exciter.

These outstanding features are responsible for the greater reliability of the Model 5140MB amplifier:

1. 15 db negative feedback provides lowest source impedance and lowest distortion into the shaker load.
2. Oversized driver tubes for high random peaks.
3. Oversized amplifier with oversized output tubes.
4. Plate dissipation capabilities exceed vibration exciter requirements by a minimum of 33⅓%.
5. Compact water systems feature "water-miser" regulation of secondary water and a demineralizer insures low conductivity in primary coolant.

For additional information on the new 5140MB Power Amplifier, write for Bulletin 134.

MB ELECTRONICS

A DIVISION OF TEXTRON ELECTRONICS, INC., 1082 State Street, New Haven 11, Conn.

NATIONAL OFFICERS

President
ARTHUR B. BILLET
VICKERS INC.

Executive Vice President
DONALD J. FOX
FENWAL INC.

Fiscal Vice President
MARK CHRISTENSEN
AEROJET GENERAL CORP.

Local Chapter Vice President
GERHARD DOERING

Membership Vice President
HERBERT J. SAUNDERS
VAP-AIR DIVISION
VAPOR HEATING CORP.

Publications Vice President
JOHN D. CAMPBELL
PHILCO CORP.

Past President
WILLIAM L. VANDAL
FORD-AERONUTRONIC

Executive Secretary
HENRY F. SANDER

DIRECTORS

Boston
RALPH MARCUS
RAYTHEON COMPANY

Chicago
JOHN D. LOSSE
AC SPARK PLUG DIVISION, GMC

Los Angeles
BRUNO J. FORSHER
AEROSPACE CORP.

Michigan
OTTO ALTMAN
LEAR INCORPORATED

Mid-Atlantic
DAN GRADY
GENERAL ELECTRIC MSVD

New York
NORMAN PONGE
SPACE-TRONICS

Northern California
CURTIS R. SEYLER
AEROJET GENERAL CORP.

Northwest
JAMES C. STUART
BOEING COMPANY

San Diego
GRANT Q. HUBBELL
RYAN ELECTRONICS

Southern Ohio
JOHN L. CAHILL
LEDEX INC.

Southern Tier
RALPH G. MEZA

VOLUME 4 NUMBER 5

OCTOBER 1961

the JOURNAL of

ENVIRONMENTAL SCIENCES

For active Environmental Engineers and the executives throughout industry who are concerned with the advancement of Environmental Engineering by the Institute of Environmental Sciences.

Henry F. Sander MANAGING EDITOR

John D. Campbell TECHNICAL EDITOR

Ray W. Kopriva ART DIRECTOR

5 A MESSAGE FROM THE PRESIDENT

7 LOCAL CHAPTER OFFICERS

8 A STUDY OF CONVECTIVE CURRENTS IN WATER

11 LOCAL CHAPTER NEWS

12 DISTURBING FORCES PRESENT IN A ROTATING SPACE STATION

14 VIBRATION TESTING AND THE PERPETUATION OF MYSTERY

16 ENVIRONEWS

20 1962 TECHNICAL MEETING COMMITTEE

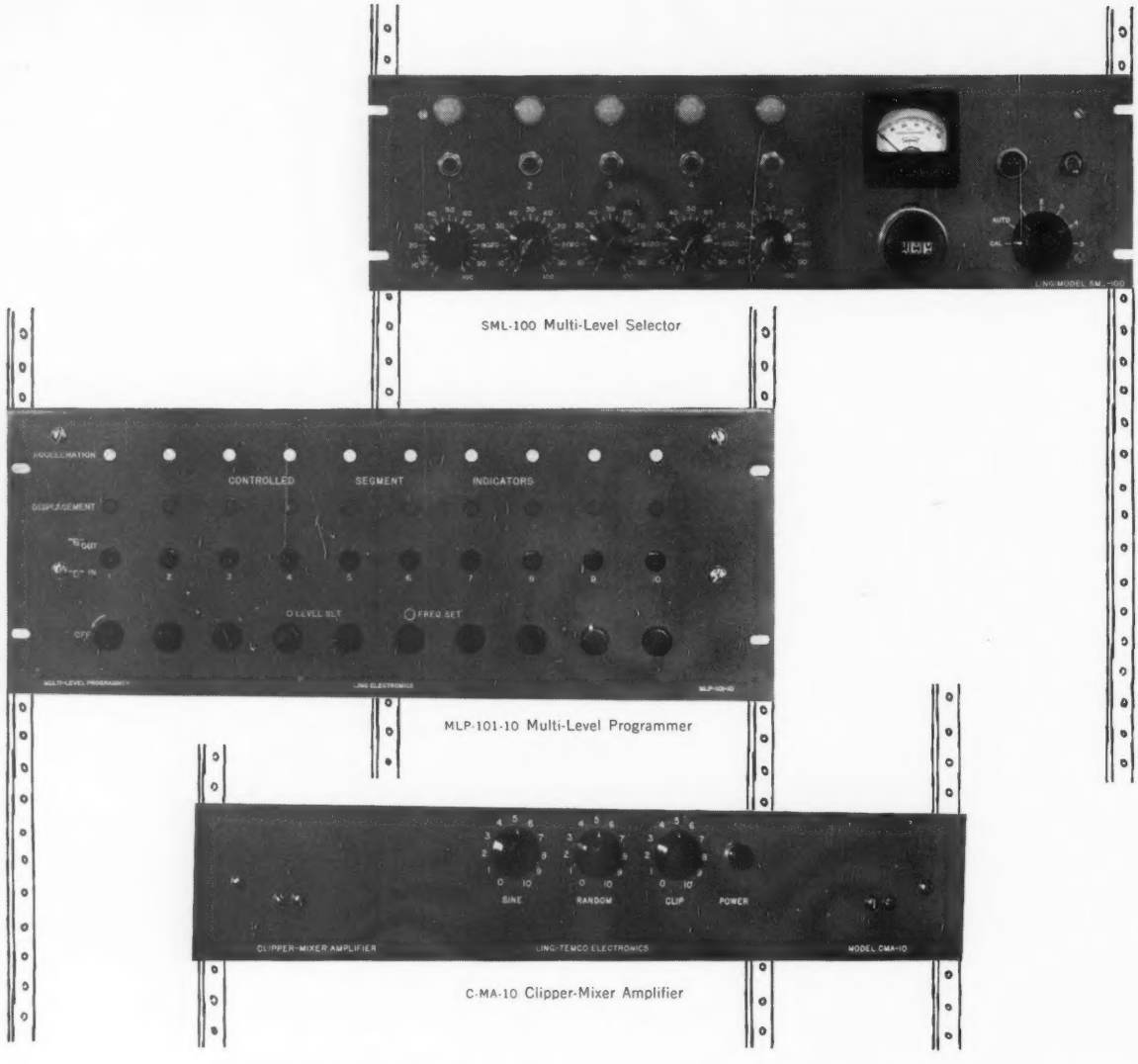
22 AUDITOR'S REPORT

THE JOURNAL OF ENVIRONMENTAL SCIENCES is published bi-monthly by the Institute of Environmental Sciences at their National office, 34 S. Main St., Mt. Prospect, Ill., CLearbrook 5-1561. The JOURNAL is circulated free to all members of the INSTITUTE OF ENVIRONMENTAL SCIENCES, and is available to others by subscription. Subscription Rates: $5.00 per year (6 issues) in United States and Possessions and in Canada. Single copies: $1.00 per copy when available. Double prices for copies more than six months old. CHANGE OF ADDR Allow 2 months. Please send old address as well as new.

Copyright 1961 by INSTITUTE OF ENVIRONMENTAL SCIENCES.

Send all correspondence regarding subscription, circulation, advertising and editorial material to the office of publication, The Institute of Environmental Sciences, P. O. Box 191, Mount Prospect, Illinois.

We cannot be responsible for unsolicited manuscripts.



LING EXPANDS INSTRUMENTATION FOR THE VIBRATION TESTING INDUSTRY – adds three new products for control and programming

MULTI-LEVEL SELECTOR: Top, Model SML-100 allows each of five accelerometer signals, calibrated for operation at predetermined "g" levels, to limit shaker excitation to package; prevents excessive excitation of critical points in test specimen. Built-in calibrator . . . panel selector for automatic operation or individual channel control . . . light indicators identify control accelerometer . . . compatible with existing servo systems. **MULTI-LEVEL PROGRAMMER:** Center, Model MLP-101-10 is manually preset for change-over at desired frequencies and then automatically holds preset "D" or "g" levels over each band of frequencies. Ten transfer points are provided. The programmer is compatible with existing servo systems. **CLIPPER-MIXER AMPLIFIER:** Bottom, Model C-MA-10 is a high quality, stable yet economical unit for level control of sine or random noise signals. An internal acceleration clipper may be switched in to provide adjustable clipping of the noise signal, and sine and noise signals may be mixed for complex wave operation. For more information on Ling systems, write Department JES-1061 at the address below.

LTV

LING-TEMCO-VOUGHT, INC.

LING ELECTRONICS DIVISION

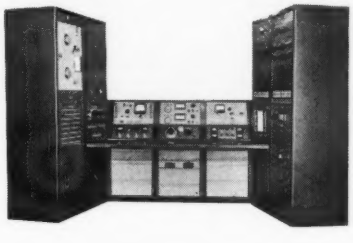
1515 SOUTH MANCHESTER, ANAHEIM, CALIFORNIA • PRospect 4-2900

LING ELECTRONICS

Here is further proof that Ling always provides vibration systems with greatest flexibility, versatility and convenience. The R1007 Master Control Console shown below is recognized the finest of its kind, and is a prime example of the human engineering incorporated into all Ling equipment.

The R1007 features a signal patch panel in which signal source, signal shaping and equalization are all connected for normal operation. By patching, equipment not used in a given test may be bypassed, or inputs to the various monitors can be changed so almost any point in the signal path can be measured. External signals can be fed into the system's read-out devices, or equipment integrated into the console may be patched for external measurements.

The patch panels graphically display signal flow from left to right and top to bottom, giving the operator a ready picture of system operation.



The R1007 offers pushbutton convenience all the way! Pushbutton selector switches are provided with measuring devices such as VTVM's, X-Y Recorder Log Convertors and Scopes to allow rapid measurement of signals at key points. Pushbuttons light up for visual monitoring.

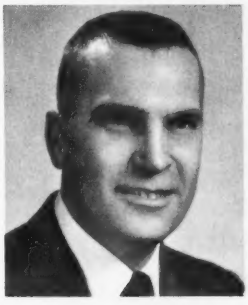
Whatever your needs in super power electronics, vibration testing, acoustics or sonar, you'll find Ling systems offer highest performance ratings, highest reliability...setting the industry standard.

LTV

LING-TEMCO-VOUGHT, INC.
LING ELECTRONICS DIVISION

HIGH POWER ELECTRONICS FOR
VIBRATION TESTING • ACOUSTICS • SONAR

A MESSAGE FROM YOUR PRESIDENT



Arthur B. Billet

During the past four months we have seen a marked increase in space achievements and technological advances from outside of the United States. Never before has our competition been stronger. We find this competition not only in international space engineering, but we find it within our own companies and between companies. This competition, whether international, national, or personal, forms the basis of our way of life; and how well we compete today will determine whether we will be allowed to continue to compete tomorrow.

No longer can we afford to do a job that is only "good enough," using the excuse of limitations of money or time. In each of our personal and professional endeavors the extra investment in hours and dollars for the "very best" effort is quickly amortized by the resulting sound competitive position for both we as engineers and the products that we represent.

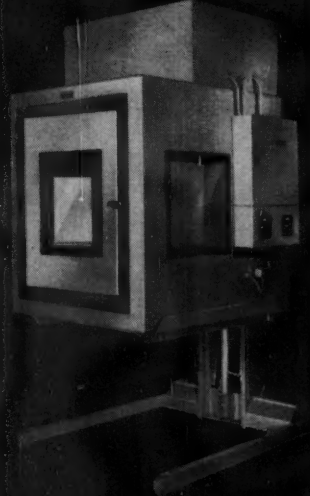
One method of providing the "very best" is to make sure that each day as we approach our appointed tasks to use the utmost in enthusiasm. The dictionary says that enthusiasm is ardent zeal or interest. Without this, there is no chance of producing our "very best." Whether our particular engineering activity involves ground support, marine applications, or space, you need enthusiasm. Enthusiasm can make your work seem easier, and this in turn helps you do a better job.

By using enthusiasm let us provide the "very best," whether it is for us personally, our company, our country, or the Institute of Environmental Sciences.

BETHLEHEM'S ThermaLine

standard chamber for simulation of combined environment

ThermaLmonarch
Mark 1



developed for use with any vibration machine

36 cu.ft. test space
48" high
36" wide
36" deep

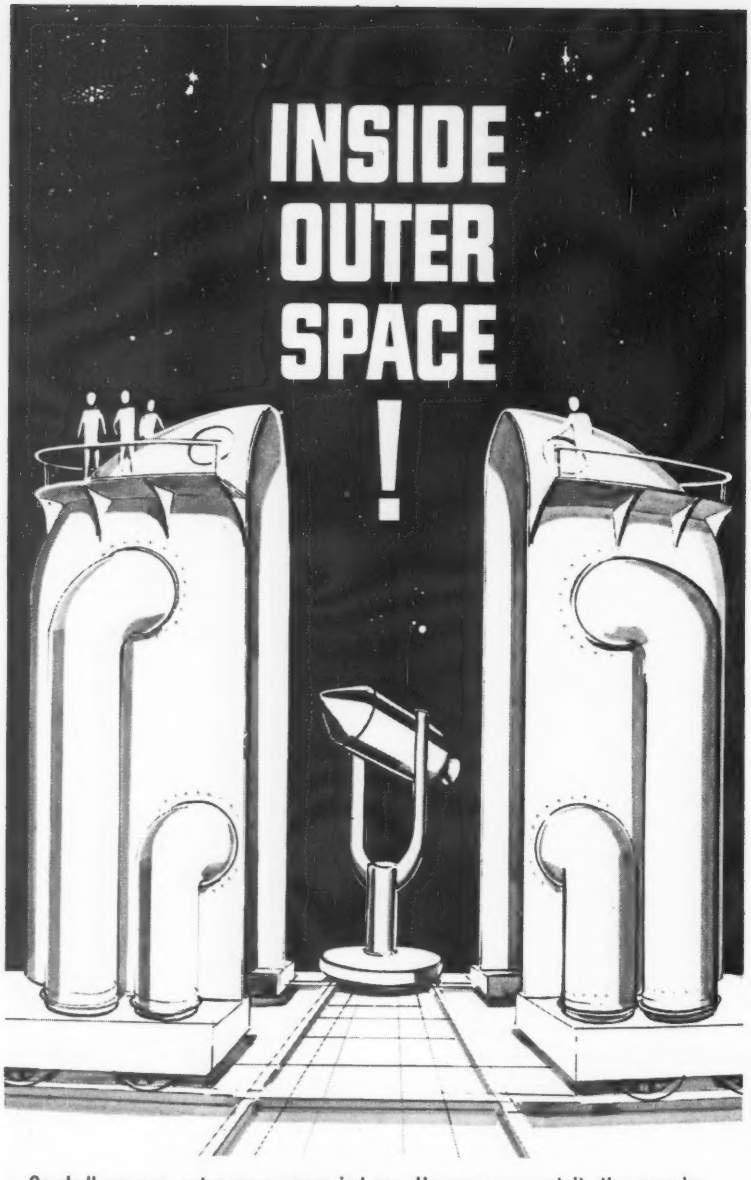
Write for Bethlehem's complete Environmental Product Catalog.

ENVIRONMENTAL ENGINEERING DIVISION

THE BETHLEHEM CORPORATION EST. 1856

225 W. SECOND ST., BETHLEHEM, PA.

OTHER BETHLEHEM DIVISIONS: SPECIAL CONTRACTS, BETHLEHEM FOUNDRY & MACHINE, PROCESS EQUIPMENT, CEMENT MACHINERY, DYNATHERM OIL HEATING.



Or shall we say, outer space goes indoors. However you put it, the meaning is the same: Tenney has brought the exotic hyper-environments of outer space down to earth — and put them into Space Simulators engineered to create, measure and evaluate the effects of extreme spacial altitudes, solar radiation, blistering heat, cryogenic cold and orbital motion. All to assure the safe and certain progress of space exploration.

Tenney's space simulation engineers, with more combined experience than any other company, can help you with your particular project. Write to Mr. Frank Gardner for further details.

Tenney ENGINEERING, INC. Aerospace Division
1090 SPRINGFIELD ROAD • UNION, NEW JERSEY
OLDEST AND LARGEST MANUFACTURER OF ENVIRONMENTAL TEST EQUIPMENT

Southern Ohio Officers. Left to right seated, John Webb, Jack Shoenberger; Standing, John Cahill, and Ed Theiss.

BOSTON

President
Elmo Pacini
Raytheon Company

Vice President
Bernard Kinney
Information Technology Labs.

Treasurer
Edward Talbot
Equipment Sales Co.

Secretary
David E. Hemingway
Richard D. Brew Co.

National Director
Ralph Marcus
Raytheon Co.

LOS ANGELES

President
Bruce Minteer
Endevco Corp.

Vice President
Seymour Seplow
Aerojet General Corp.

Treasurer
Donald E. Hughes
Don Hughes Co.

Executive Secretary
James O. Reece
Mar-Tec Electronics

Recording Secretary
Robert H. Levine
United Testing Lab.

National Director
Bruno J. Forsher
Aerospace Corp.

LOCAL CHAPTER OFFICERS

CHICAGO

President
Robert O. Scholle
Inland Testing Labs.

Vice President
Richard S. Proch
Bell & Howell Co.

Treasurer
Matthew A. Gartner
Control Switch Div. of
Controls Co. of America

Secretary
Roman R. Kubala
Webcor Testing Labs.

National Director
John D. Losse
AC Spark Plug Div. of GMC

MICHIGAN

President
Frank W. Hallstein
Bendix Aviation Corp.

Vice President
James P. Monroe
Lear Incorporated

Treasurer
Glen Blaske
Vickers Incorporated

Secretary
Arthur Grieves
Vickers Incorporated

National Director
Otto Altman
Lear Incorporated

MID-ATLANTIC

Chairman
Peter Zukauskas
The Martin Co.

Vice Chairman
Frank Klekotka
Heinemann Electric Co.

Treasurer
Richard H. Tuft
General Electric MSVD

Secretary
Edward Toleikis
Radio Corporation of America

National Director
Dan Grady
General Electric MSVD

NEW YORK

Chairman
Richard Hahn
U.S. Testing Co. Inc.

Vice Chairman
Carmine Colaluca
Republic Aviation Corp.

Secretary-Treasurer
Frank Culmone
Fairchild Camera & Inst.

National Director
Norman Ponge
Space-Tronics, Inc.

NORTHERN CALIFORNIA

President
John A. Biberdorf
Philco Corp.

Vice President
Donald E. Richardson
Lockheed Aircraft Corp.

Treasurer
George S. Solakian Jr.
Sylvania Electric Products

Corresponding Secretary
William T. Cathcart, Jr.
Lockheed Aircraft Corp.

Recording Secretary
Leon V. Omelka
Lockheed Aircraft Corp.

National Director
Curtis R. Seyler
Aerojet General Corp.

SOUTHERN TIER

Chairman
Stanley A. Warner
General Electric Co.

Vice Chairman
Edmund L. Dana, Jr.
Westinghouse Electric Co.

Treasurer
Rudy Janasak
IBM

Secretary
Loye H. Powell
IBM

National Director
Ralph G. Meza
IBM

NORTHWEST CHAPTER

President
Stanley E. Baber

Vice President
Elmer Neal

Treasurer
Richard Eustice

Secretary
C. L. Bommarito

National Director
James C. Stuart
The Boeing Company

SAN DIEGO

President
James D. Peterson
GD/Astronautics

Vice President
Mitchell R. Christensen
San Diego Test Lab.

Treasurer
Daniel T. Kuczon
GD/Astronautics

Recording Secretary
C. C. Campbell
G/D Astronautics

Executive Secretary
Roy D. Johnson
Pacific Scientific Co.

National Director
Grant Q. Hubbell
Ryan Electronics

SOUTHERN OHIO

President
Jack N. Schoenberger
Bowser-Morner Testing Lab.

Vice President
Earl Bruns
Westinghouse Electric Corp.

Treasurer
Edward C. Theiss
W.A.D.D.

Secretary
John W. Webb
Ledex Inc.

National Director
John L. Cahill
Ledex Inc.

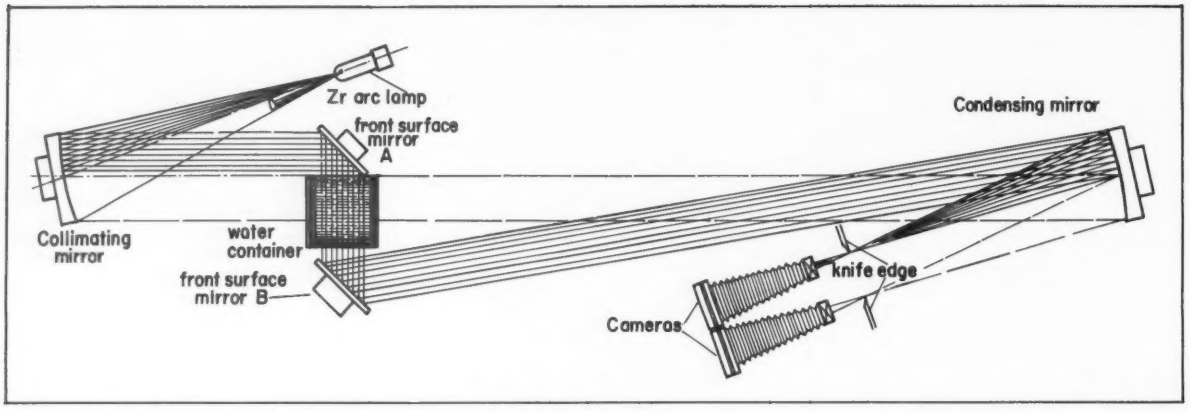


FIGURE 1

Diagram of the schlieren optical system used at the National Bureau of Standards to obtain simultaneous top and side views of convection phenomena induced in water by evaporation. The knife edges at the focal point of the condensing mirror separate the deviated light rays to produce the schlieren image.

A Study of Convective Currents in Water

The Toepler schlieren method was used in a recent study at the National Bureau of Standards to observe the convective currents that occur in water exposed to normal evaporative cooling. Experimental results, in line with those derived theoretically by other investigators, will be of aid to engineers and scientists dealing with thermal convection problems.

Vigorous and persistent mixing motions were observed in quiescent-appearing water by means of a schlieren optical system, in recent National Bureau of Standards experiments. These motions, which took the form of plunging vertical sheets with occasional columnar plunging, were convective currents induced by the normal evaporative cooling of the surface layer. The experimental results indicate that such phenomena occur naturally and continuously in any lake, pond, or other body of water exposed to still air, and that they become increasingly vigorous when the air circulates freely over the surface. These findings help to explain some of the convection phenomena observed in fields such as oceanography, meteorology, astrophysics, and hydraulic engineering.[1]

A number of attempts have been made, under idealized and rigidly controlled conditions, to verify experimentally the theoretical solutions for predicting the onset of thermal convection in fluids. A few measurements have been made of uncontrolled natural phenomena, but these measurements have required the presence of a sensing element within the fluid which may have affected the results. In the present study, by W. G. Spangenberg and W. R. Rowland of the Bureau staff, a schlieren system normally used for supersonic aerodynamic studies was employed to serve as a remote indicator for defining the movements of transparent liquids. In liquid, as in air, refractive-index changes produced by small temperature differences permit the study of the circulation taking place as a result of these same temperature differences.

To conduct the experiments, a tank of ¾-in. thick plate glass, with an inner cross section of 21 by 37 centimeters and a depth of 10 centimeters, was filled with tap water, covered, and placed in the collimated light beam of the schlieren system. With the aid of additional plane mirrors and prisms, both top and front views of the water could be simultaneously recorded by duplicate cameras.

Mercury thermometers, calibrated to 0.1°C, were used to measure temperature differences between the liquid and the ambient air. A 20-junction thermopile, made of 0.003-in. diameter wire, was used to measure temperature gradients within the liquid to the nearest 0.01°C. The reference junctions were connected to a temperature-stabilizing massive holder near the bottom of the tank; and the indicating junctions were connected to a screw-controlled traversing mechanism to obtain temperature measurements throughout the liquid.

When the tank cover was removed, natural evaporation caused a cooled film or layer to grow downward within seconds from the water surface, increasing in thickness to a depth of 6 to 7 mm. Protuberances then developed which ex-

REFERENCE

[1]For further technical details, see Convective circulation in water induced by evaporative cooling, by W. G. Spangenberg and W. R. Rowland, Physics of Fluids *4*, No. 6 (June 1961).

tended into the unaffected liquid below. Shortly thereafter, sheets of liquid plunged precipitously from the cooled surface layer, and dissipated by diffusion.

From continuous monitoring of the schlieren image, it was apparent that the forms taken by the plunging sheets were time dependent. They grew and faded and continuously changed, sometimes appearing straight, sometimes curved, and branching or terminating with no regular pattern of movement. This type of circulation contrasts sharply with the cellular circulation mode usually reported. After the tank remained undisturbed for several hours, the circulation apparently reached a steady state. Plunging was then only occasionally visible in the side view, mainly when the ambient air was disturbed. Dense stripes observed in the top view, however, did not disappear; they continued to grow and fade alternately, even after a period of several days. When the evaporation rate was accelerated by raising the water temperature, additional plunging sheets per unit area formed, probably to accommodate the larger volumes of liquid cooled at the higher evaporation rate.

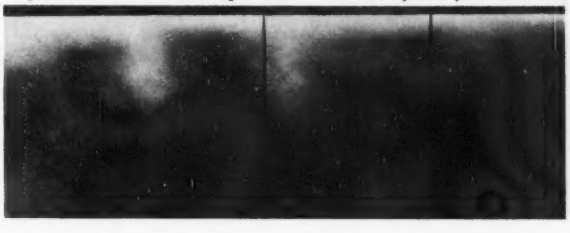
Columnar plunging occasionally occurred, the columns appearing both singly and in groups within the cooled sheets, and also at isolated points removed from other disturbances, with both the columns and sheets appearing simultaneously. Apparently, distinctly different sets of conditions are not required for the two circulation modes. However, the plunging columns were always transient manifestations. A few seconds after formation they spread into sheets which interlaced with others to form branched patterns or cells.

Temperature differences were measured with the thermopile at different depths in the body of the liquid, before and after the onset of convective currents. The temperature differences between the sheets and their surroundings also

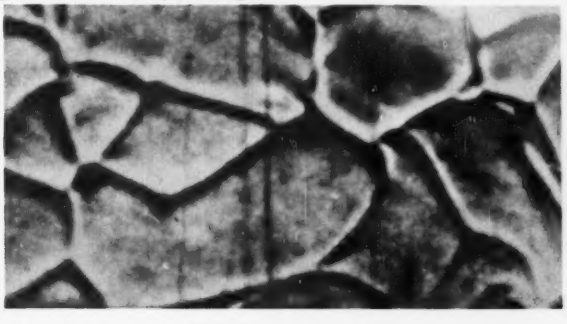
Continued on page 26

FIGURE 2

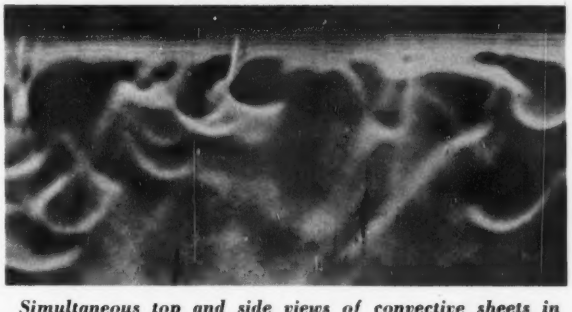
By means of a schlieren optical system, convection phenomena in water were photographed on 16 mm motion picture film in recent NBS experiments. Some of the frames were enlarged to show the following:



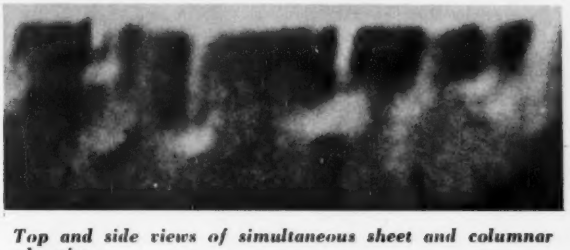
Side view of an uneven surface layer (white area) cooled by natural evaporation immediately before the onset of thermal convection. The black strip at the top is the meniscus.



Top view of a web-like pattern appearing on the water surface after convection starts.



Simultaneous top and side views of convective sheets in water. The side view indicates the constantly changing patterns that appeared as intertwining filaments during the experiments.



Top and side views of simultaneous sheet and columnar plunging.

Watch for the Preliminary Technical Program for

THE INSTITUTE OF ENVIRONMENTAL SCIENCES 1962 TECHNICAL MEETING

The mailing will be made in November 1961. Please see page 20 in this issue of The Journal.

MM THE FINEST IN

ENVIRONMENTAL TEST EQUIPMENT

DEPENDABLE operation and accurate tests can only be assured through constant research and the use of highest quality materials and workmanship. Murphy & Miller test equipment is manufactured to the highest standards with quality the prime objective. The true meaning of dependability becomes vital when it is considered that an entire production schedule often hinges upon . . . a dependable test.

MURPHY & MILLER Inc.
ENVIRONMENTAL TEST EQUIPMENT

600 West Taylor Street, Chicago 7, Illinois

ETL

SPECIALISTS IN *LABORATORY* MEASUREMENTS

ELECTRICAL
ELECTRONIC
PHYSICAL
PHOTOMETRIC
CHEMICAL

at

SPECIFIED ENVIRONMENTAL CONDITIONS

Bulletin available on request.

Specializing in:

- **Measurements at microwave frequencies**
- **Calibration of instruments and standards**
- **Qualification tests per Mil-Specs.**

Member—American Council of Independent Laboratories

ELECTRICAL TESTING LABORATORIES, INC.

2 East End Ave., New York 21, N. Y.

BUtterfield 8-2600, Area Code, 212

J. Dombrowski (left) of Bendix Corp., Scintilla Div. demonstrates their Automatic Centrifuge to touring members of the Southern Tier Chapter. The centrifuge holds up to forty circuit modules which are automatically programmed through a series of electrical tests combined with temperature extremes and constant acceleration.

LOCAL CHAPTER NEWS

The **Boston** Chapter held their August meeting at AVCO's RAD facility. Their speaker was Mr. Charles E. White, Chief of the Laboratory Measurements Section at AVCO. His topic was "Measurements Using Calibration Standards." The Program Chairman for the Boston Chapter is Mr. Donald Jenkins of the Measurement Equipment Company.

The **Chicago** Chapter had Dr. Edward B. Magid of W.A.D.D. for their September meeting speaker. Dr. Magid was the Award winning speaker for the 1960 Technical Meeting in Los Angeles. In Chicago Dr. Magid spoke on the effect of the dynamic forces on man during launch, high speed flight, reentry and transient acceleration phases of rocket propelled manned space vehicles. He explained the vibration criteria of human limits of comfort, safety and performance during flight. The biological stimulus of applied mechanical forces and the resultant displacement of body parts with relation to one another was also discussed. Dr. Magid's paper appears in the 1960 Meeting Proceedings.

The **Los Angeles** Chapter recently had a panel discussion devoted to hydraulic shakers. Each panel member presented a topic. These were, "Fundamentals of Hydraulic Shaker Systems" by Mr. Jay Adler of Vard Division Royal Industries, "Comparisons with Electromagnetic and Mechanical Shakers" and "Applications of the Norair Hydraulic Shaker" by Mr. Warren Schreger of Norair, and "Missile Testing with Hydraulic Shakers" by Mr. J. J. Kavenaugh of Convair. They plan to have another panel discussion on "The Problem of High Altitude Simulation" at their October meeting.

The **Southern Ohio** Chapter has not reported any activity for some time. Members in this area are requested to contact the Chapter President, Jack Schoenberger of Bowser-Morner Testing Labs in Dayton, Ohio.

The **San Diego** Chapter's September meeting consisted of a presentation by Mr. Robert E. Clautice of Minneapolis-Honeywell. His presentation described some of the techniques and problems involved in measuring the spectra of related phenomena. In particular, the measurement of cross-spectra by analog methods was treated. The areas of application of these techniques lie in the fields of transfer function studies relating to structures, vibration, acoustics, and other phenomena as encountered in sonar, seismological of R. F. propagation studies and in the field of medical diagnosis.

The **Northern California** Chapter held their October Meeting on the 2nd. Mr. L. P. Smith of Aerojet General Corp. spoke on "High Altitude Simulation Testing for Both Liquid and Solid Propulsion." John Biberdorf of the Philco Corp. reports the chapter's lecture series at Palo Alto and Sacramento are a success.

The **New York** Chapter had their September Meeting in Clifton, New Jersey where Mr. Kakatskis of AVCO spoke on "Shock Test Equipment." The familiar but tricky subject of matching shock test results to the specified impulse wave form in currently applied commercial and military documents was discussed. The lecture yielded some fresh thoughts on a subject which is a never ending source of discussion. Their October meeting is to be a tour of the M.B. Electronics plant in New Haven, Conn.

Only Associated's vibration slip table gives you all these features

Model VTA-18-24 Price $1950

Designed to increase shaker payload performance of any vibration test system, Associated's oil film slip tables incorporate features unavailable in other auxiliary vibration tables. For example:

- Internal air lift, operates from 15 psi supply, permits fast, one-man positioning.
- Sand filled base for maximum mass and rigidity at lowest cost.
- Frequency range from 1 to 3500 cps.
- Less than 5% vertical crosstalk, less than 20% horizontal crosstalk.
- Heights to user specifications, no adjustments needed.
- Useable in environmental chambers from −150°F to +200°F.

Available with 18" x 24" and 36" x 36" table areas. Complete specifications and prices in Bulletin C-21.

Associated

ASSOCIATED TESTING LABORATORIES, INC.
(Manufacturing Division)
136 ROUTE 46 • WAYNE, NEW JERSEY • CLifford 6-2800
TEST LABORATORIES
Wayne, N.J. • Winter Park, Fla. • Burlington, Mass.

DISTURBING FORCES PRESENT IN A ROTATING SPACE STATION

By G. T. BEAUCHAMP

Lockhead Aircraft Corporation
Missile and Space Division

This paper is based upon material presented at the Seventh Annual Meeting of the American Astronautical Society in Dallas, Texas on January 16, 1961.

When a vehicle is projected into space as a satellite in orbit about the earth, a decision must be made regarding the gravitational environment of the crew. While information on zero gravity states is somewhat vague at this time, there is a wealth of information on induced gravity states. The effects of such states are discussed in this paper, which considers a space station in the form of a wheel.

It is easy to induce artificial force simulating gravity by rotating a vehicle about an axis. This artificial force is, of course, centrifugal and acts radially. The force acting upon a man in a vehicle designed to operate in this manner will be downward—from head to foot. The simulated gravity acts generally the same as natural gravity, but because of the size of the vehicle and its angular velocity, an additional component is present.

This additional component, called the Coriolis force, is present wherever movement within a rotating vehicle takes place. It is present on the earth, but here the magnitude is so small that it is not normally noticed. In gunnery tables, however, provision must be made for the Coriolis force when long ranges and varying latitudes are involved. In a space vehicle, the magnitude of the force is relatively great and will most certainly place severe limits on the use of simulated gravity and, also, restrict vehicle sizes.

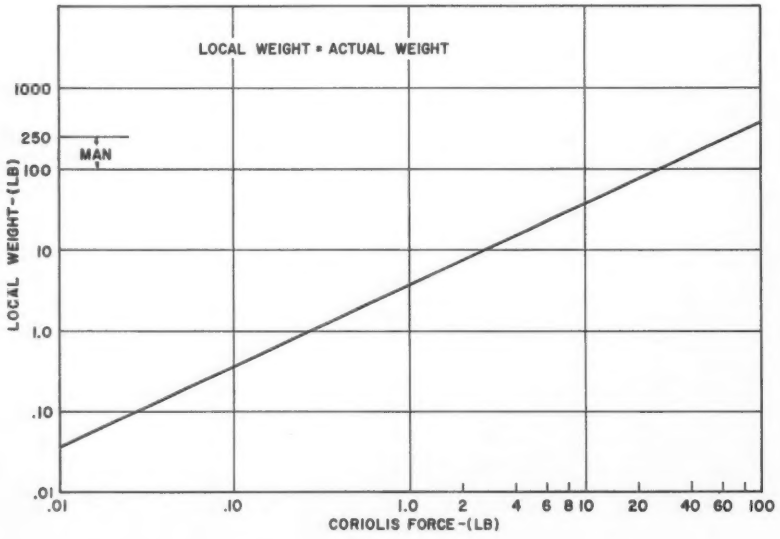


FIGURE 1

Coriolis force vs. man's local weight. (Based on 1.0-g simulation, 20 ft. vehicle radius and 3.5 fps speed of movement.)

Centrifugal acceleration or simulated g is expressed by

$$\omega^2 r = ng \qquad (1)$$

where n is the required number of g's.

Coriolis acceleration is given by

$$2\vec{\omega} \times \vec{V}$$

where $\vec{V}$ is the velocity of movement of a body relative to a rotating vehicle.

Hence, the Coriolis force F_{cor} is

$$2\omega \text{ Vm/g lb}$$

where m is expressed in poundals.

By substituting equation (1) for ω, a general equation results:

$$F_{cor} = 2\sqrt{ng/r}\ \text{Vm/g}$$

A more convenient form is:

$$F_{cor} = 2V\sqrt{m^2 n/gr}\ \text{lb force}$$

where

V = velocity of a body relative to a rotating vehicle (ft/sec)
m = weight of body (lb)
n = required number of g's
r = radius of vehicle (ft)

The effect of Coriolis components on a

seasoned crew member moving in a rotating space vehicle is probably perplexing. For example, if it is assumed that a vehicle has a 20-ft radius and is spun to simulate a 1.0-g field ($= 1.26$ radians/sec), a 150-lb man climbing up a ladder from the periphery to the hub at 3.5 ft/sec will experience a 41-lb force (Fig. 1). The direction of this force will be the same as that of the vehicle rotation (Fig. 2). Although the force will act through the man's center of gravity, the problem becomes complicated because his limbs will be moving upward at different speeds from his gross climbing speed and will themselves be subjected to differential Coriolis forces. Hence, it is desirable to eliminate ladder climbing in a rotating space vehicle and use lifts as a means of moving to and from the hub.

The choice of one gravity or of fractional gravities lies with the vehicle designer and the human factors scientist. Structural considerations have been one of the selling points favoring low gravity. Reference to Figs. 1 and 3 clearly shows that there are definite restrictions in the choice of gravity levels. Literature on manned space vehicles has stated that the simulated gravity would be 0.10 normal gravity, but serious disadvantages are revealed. By making the same assumptions as before and referring to Fig. 3, it is found that the Coriolis force on the man is 13 lb. However, at 0.10 g, man's local weight is not 150 lb; it is 15 lb. Thus, the force acting on him under these conditions is almost equal to his local weight and such a situation is, of course, intolerable. The situation could be eased somewhat by reducing the rate of man's movement to 1 ft/sec, but even then the Coriolis force is 3.75 lb which represents 25% of a man's local weight. Clearly, the use of very low gravity levels is contra-indicated.

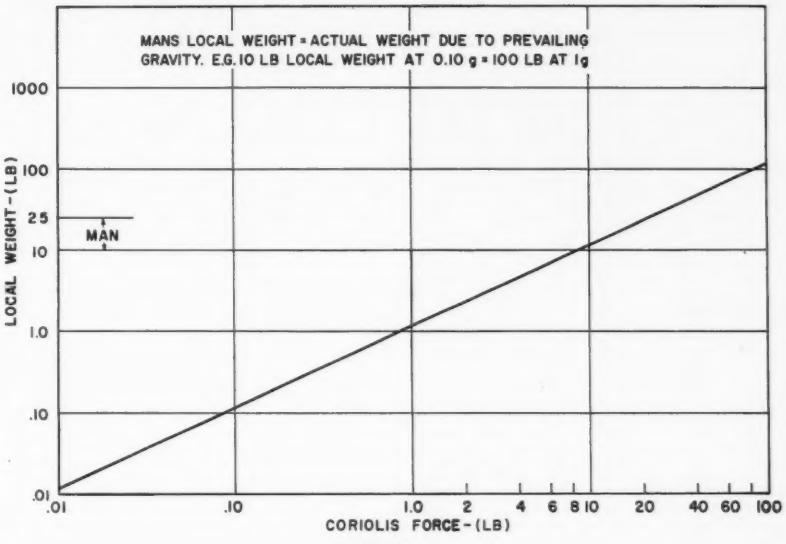


FIGURE 3

Coriolis force vs. man's local weight. (Based on 1.0-g simulation, 20 ft. vehicle radius and 3.5 fps speed of movement.)

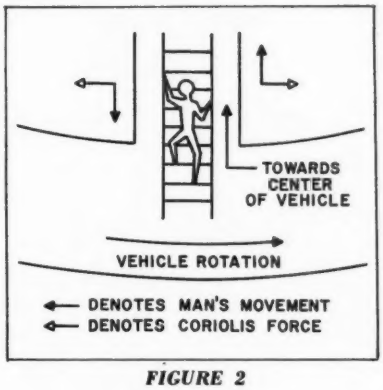


FIGURE 2

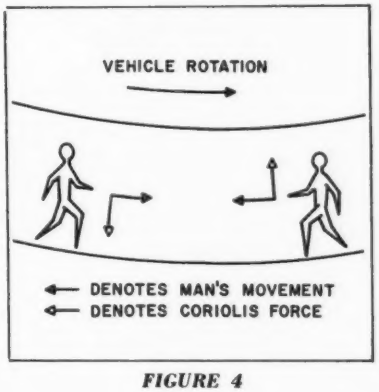


FIGURE 4

For a 0.50-g simulation, given the same conditions as before, the Coriolis force is about 29 lb. This, when related to the man's local weight of 75 lb, is an improvement but still represents about 38.5% of his local weight. By increasing the gravity level to 1.20 and restricting movement to 1 ft/sec, the Coriolis force is reduced to 12 lbs, or 7% of the man's local weight.

It is evident that by carefully considering vehicle size and the magnitude of the simulated gravity, and by making allowance for slower movements, it is possible to reduce the awkward and perturbing effects of Coriolis forces.

Coriolis forces are also felt when there is movement with or against the direction of the vehicle rotation (Fig. 4). When an object in the plane of rotation moves *against* the vehicle rotation, Coriolis force will subtract from the local weight of the object and will act in an upward direction. Conversely, when an object in the plane of rotation

Continued on page 21

About the Author

Mr. G. T. Beauchamp has been with the Lockheed Space and Missile Division for the past five years as a Design Specialist in the Advance Planning Division. Prior to this he spent three years with the Hawker Aircraft Ltd. as an Assistant Group Engineer. He also was employed for fourteen years as Senior Fighter Designer of Spitfires and Jets at Vickers Armstrong Ltd.

Mr. Beauchamp received his Aeronautical Engineering Degree in England and has continued his education in the U.S.A. He is an Associate of the Royal Aeronautical Society, a Fellow of the British Interplanetary Society, a Member of the American Rocket Society, Senior Member of the American Astronautical Society, and a Member of the Aero/Space Medical Association.

About The Author

Mr. Fromkin received his Bachelor of Science degree in Physics from U.C.L.A. in 1950 and is currently working on his M.A. in Mathematics.

He presently is the Director of Research and Development at Rototest Laboratories and has held this position for the past five years. Mr. Fromkin has been the author of many articles dealing with Acoustic Testing and Vibration Testing.

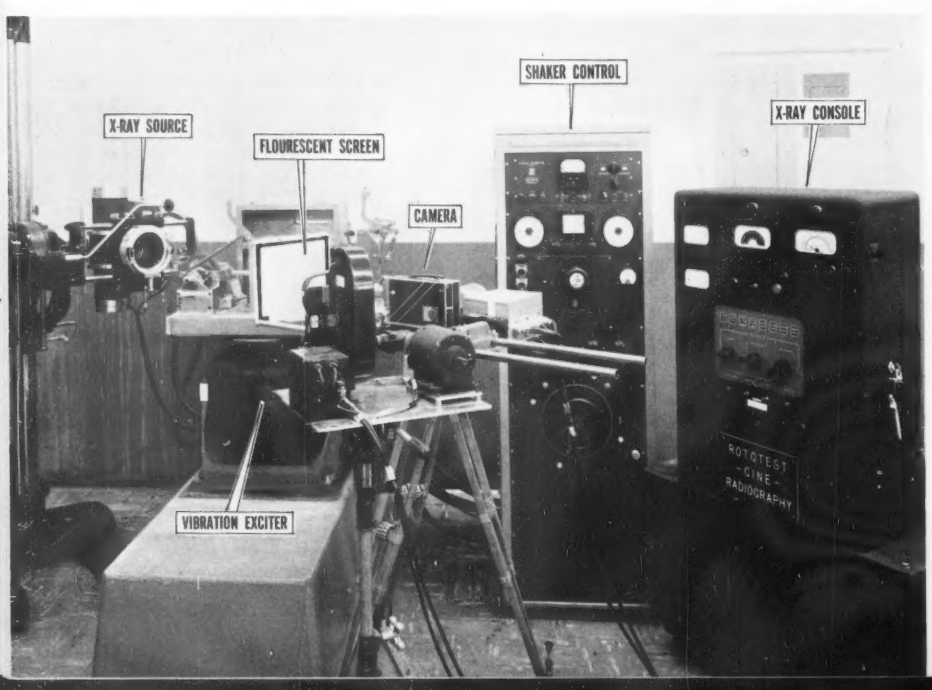
VIBRATION TEST

BY JACK FROMKIN Rototest Laboratories

There is an old story about the man who, having dropped a coin in a darkened portion of the street, searched busily under a street lamp because it was easier to see there. It is the purpose of this paper to demonstrate that this story is an analog of the present state of vibration testing. It is a further purpose of this paper to encourage renewed searching in the dark areas.

To begin, it is useful to note that, although vibration is only one of many existing environmental stresses, it accounts for a disproportionate share of the malfunctions and failures observed. This is not to imply that other environments do not have deleterious effects. It is, rather, to emphasize the fact that, while good progress has been made in design to combat these environments, little progress has been made in the area of anti-vibration design.

The consequences of this lack of progress are more than academic. For example, it has been observed that, of all items submitted for initial vibration testing, some 80 to 85 percent malfunction or fail structurally. This figure has been confirmed by discussion with at least one missile prime contractor and various government agencies. These failures have required at least one redesign and, in some cases, abandonment of a design after a number of unsuccessful redesign attempts. It is precisely here, where testing should provide the knowledge needed for redesign, that present methods of vibration testing have failed to be of utility. In view of the fact that the above percentages of failure have been obtained with vibration inputs up to 35 G and with the knowledge that specifications for newer vehicles extend up to 200 G, it is mandatory that existing test methods be examined and modified. Some discussion of the difficulties of design and testing is, therefore, merited.



Cine-Radiography Vibration Test Facility

The primary difficulty of design is that analytical treatment of a given package is exceedingly complex. The present analytical approach is borrowed from electrical filter theory and postulates an output as a product of an input and a transfer function. While this approach is fruitful in electrical circuit work, it has as fundamental assumptions some things which can rarely be justified in vibration work. Among these is the assumption of a well-defined set of input and output terminals. Further, in an electrical filter system there are, at most, two directions of transmission (forward and reverse) which are of interest. In vibration work there are n directions of interest with the distinct possibility that $n \rightarrow \infty$. Thus, in electrical filter work one need not be concerned with additional inputs of arbitrary phase, amplitude, direction and even frequency which may appear at another set of input terminals.

Assuming, however, that inputs could indeed be confined to one set of terminals, it is of interest to observe the resulting transfer functions. A glance at a mechanical impedance curve is sufficient to indicate that the transfer functions are discontinuous. (In fact, so many discontinuities appear, that it is a matter of some interest to determine what happens at these points.) Further, the transfer function varies in a non-linear fashion with input amplitude. It is small wonder, then, that successful analytical treatment has been applied only to geometrically elementary configurations and even then with the assumptions of uncoupled resonators and rather light damping.

Since, from the above, prediction of vibration response for a typical package, is exceedingly difficult, knowledge of the response *must* come from the testing process. If knowledge is not obtained here, then indeed, the mystery has been perpetuated and the notion of reliability must be replaced by the notion of good fortune. It is of interest, then, to examine typical vibration testing procedures.

The most usual testing situation shows a test specimen mounted on a holding fixture which is in turn mounted on a vibration exciter. One or more accelerometers are used to monitor the input and, occasionally, one or more accelerometers are mounted on the case

TESTING AND THE PERPETUATION OF MYSTERY

of the test specimen. These accelerometer outputs are fed to a complex of control and analysis equipment from which emerges a closely controlled (within limits) vibration input and response curves taken from the case. There is no attempt to observe the internal dynamics of the package! ! Here lies the crux of the matter. This procedure is equivalent to applying a carefully controlled input to a filter of unknown transmissibility and *not* measuring the output. While this procedure may be of interest, it cannot be called testing. There is, of course, output information taken from the case, but case performance is not the area of interest. In fact, case malfunction (whatever it may be) would be a good trade for proper functioning of the internal operating mechanism.

There is, of course, an attempt to judge the effects of vibration on the performance of the test speciment by monitoring one or more operational parameters. However, the information content of this process is slight. Actually, only two questions are answered by this monitoring process. These are:

1. The test specimen did/did not malfunction under this specific vibration input.
2. The test specimen did/did not break under this specific vibration input.

There remains some sizeable number of questions which this procedure does not answer. Some of these are:

1. If the test specimen did not malfuction or break,
   a) How long will it continue successfully?
   b) At what input level will it fail?
   c) What are the points of maximum stress?
2. If the test speciment did malfunction or break,
   a) Why did it fail?
   b) What is the *specific* cause of failure?
   c) How can it be redesigned to preclude this failure?

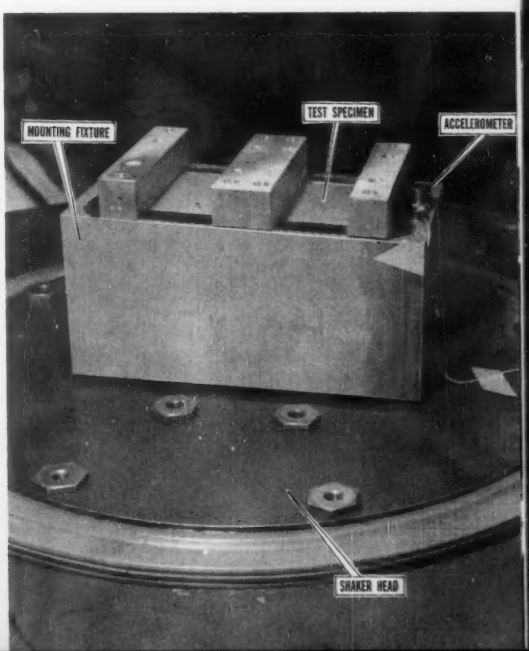
A closer look at this monitoring process exposes some of its difficulties. First assume that, as happens often, malfunction without structural damage takes place. In general, this malfunction ceases when the vibration input is removed. A static study of the test specimen then reveals nothing. The last recourse is to deduce from the logic of test specimen operation "what must have happened." This is a dangerous basis on which to place missile reliability.

Next, assume that structural damage has occurred and exists as a clue. Here the fact must be faced that the member which fails is not necessarily the primary cause of difficulty. The complex couplings within a typical package are such that the failure may be the result of a chain of events whose origin is on the other side of the package. "What must have happened" is not easy to deduce. In fact, the difficulties of "vibration sleuthing" are best illustrated by the following problem which is drawn from an actual experience: Let a resistor and a capacitor be connected as a differentiating network. Let them be mounted by any means whatsoever on a vibration exciter. Let the criterion for performance be the time constant of the network as monitored by any convenient means. Assume now that, under vibration, the time constant changes by 40 percent. Is this change due to the resistor, the capacitor, or both? Let the vibration be continued or increased until one or more leads on either the capacitor, the resistor, or both are broken. Was the time constant change due to the resistor, the capacitor, or both?

The difficulties inherent in this process are such that one is tempted to remove the case in an effort to see (if possible) what is happening. Here, two further difficulties arise. The first is that the removal of the case changes the dynamics of the package drastically. The second is that the removal of the case brings to light an array of further encased components, so that "seeing" is only slighted improved.

All of the above is meant to point out the serious weaknesses of vibration testing. There are more problems than have been discussed, for example, the differences in driving point impedance exhibited by a vibration exciter and a missile bulkhead or the accuracy of measurements from which vibration specifications are deduced. However, work done to date has not been in vain. It has served to etch clearly the problems discussed and to indicate that present methods of vibration testing are inadequate. It has also led the writer to an opinion which may merit some discussion. This opinion is that there is no "prototype" for a production run of packages so far as vibration is concerned. There is as little reason to expect uniformity as ther would be with regard to a production run of I.F. amplifiers before alignments. Differences in materials, the riveting of a turret lug, the tension in the pigtails of components, the tightening of nuts and bolts, the smoothness of butting or lapping joints, the soldering of connections are all variables which determine the "tuning" of a package. It is not surprising then, that five packages selected at random from a production line fail at widely varying vibration input levels. Nor is it surprising to find a successful prototype and a failing production run. It is when these difficulties lead to demands for closer control of the input, rather than investigation of the output that searching under the street lamp begins. It is, admittedly, easier to study the input. The treatment is analytical and the results are realizable in the form of adequate, if expensive, hardware. However, the ability to analyze and control a random noise signal in 20 cps bandwidths rather than 100 cps bandwidths brings us no closer to the goal of knowing the behavior of the test specimen. Further, when these demands are coupled, in some cases, with the grant-

Continued on page 18



Usual Vibration Testing Situation

ENVIRONEWS

This column is newly created to supply the readers with news items of general interest. Topics to be covered will be: Abstracts, Book Reviews, Education, Facilities, Member's News, New Products, Publications, and Services.

ABSTRACTS

METHOD OF DESIGNING SOLAR THERMOELECTRIC GENERATORS

By V. A. Baum and A. S. Okhotiu (U.S.S.R.)

An attempt is made to establish a practically convenient method for the technical design of Solar TEG's which allows us to ascertain the possibility of their use under different conditions and to trace the effect of different factors on their working.

Photocopy available from the John Crerar Library, SLA Translations Center, 86 E. Randolph St., Chicago 1, Ill. #61-13332, 5 pages, $1.80.

CRYOPUMPING CHARACTERISTICS OF NON-CONDENSIBLE GASES

By: O. O. Haroldsen and A. Cohen

A series of tests were made to determine the rate at which hydrogen gas could be frozen on helium cooled heat exchangers fins located inside a vacuum chamber. The hydrogen gas was allowed to pass into the vacuum chamber and the vacuum chamber pressures at various hydrogen gas flow rates were recorded. An analysis was made to correlate the test results with theoretical calculations.

Obtained in the 1961 Meeting Proceedings.

LIQUID PROPELLANT STORAGE IN EARTH SATELLITE ORBITS

By Roger Burry.

The feasibility of liquid propellant storage in earth satellite orbits is investigated through consideration of the radiative heat exchange between the satellite and its orbital environment. Both thermal equilibrium and propellant loss conditions were considered in the comparison of the "relative storability" of various propellants. Radiation shield and surface characteristics requirements are indicated for the storage of propellants ranging from low temperature liquid hydrogen to relatively high temperature hydrazine.

This paper available from the Institute of Environmental Sciences, Postoffice Box 191, Mt. Prospect, Ill. 25 pages, $0.50.

BOOK REVIEWS

THE CHEMISTRY AND VERTICAL DISTRIBUTION OF ATOMIC NITROGEN IN THE UPPER ATMOSPHERE

By Lewis E. Miller
Air Force Research Division, ARDC
L. G. Hanscom Field, Bedford, Mass.

The topic, "The Chemistry and Vertical Distribution of Atomic Nitrogen in the Upper Atmosphere," may be regarded as a unit of a larger field, that of free radical chemistry. Atomic nitrogen like other free radicals is characterized as being electrically neutral and possessing an odd number of electrons. This later characteristic accounts, in part, for its short lifetime and its highly reactive nature. An intensive and extensive review and analysis based on some 540 papers covering various aspects of the discovery of active nitrogen in the laboratory and the identification of atomic nitrogen in auroral and night airglow spectra have been summarized and given in tabular form. An integral part of the existence of atomic nitrogen in the upper atmosphere is the absorption of ultraviolet radiation by molecular nitrogen. Consequently such topics as absorption coefficients, dissociation energy of molecular nitrogen, discovery of the negative bands of N_2+, and the various band systems of N_2 are included. More recently there has been an acute emphasis on the rates of free radical reactions and recombination coefficients. So far as is possible these data have been presented within the various summaries. The author and subject indices should aid in making this treatise a valuable and informative reference source.

A copy of this book is available from the Office of Technical Services (#AFC-RL-TR-60-280), Department of Commerce, Washington 25, D.C.

HANDBOOK OF ASTRONAUTICAL ENGINEERING

Heinz Termann Koelle, Editor. Prepared by a staff of specialists. With a Foreward by Wernher von Braun. 1814 pages plus index; 1052 illustrations; 6 x 9; McGraw-Hill Handbook Series. $27.50. Publication date: October, 1961.

The "Handbook of Astronautical Engineering" is the first summarization between two covers of the present state of the art of Space Flight Technology. Prepared by a team of 150 leading specialists from government agencies, industry, and universities, the Handbook is the culmination of three years' work screening thousands of books, articles, and reports for the essential information and data required by the design engineer and scientist to design the space vehicles of today and the future and to calculate their performance and cost.

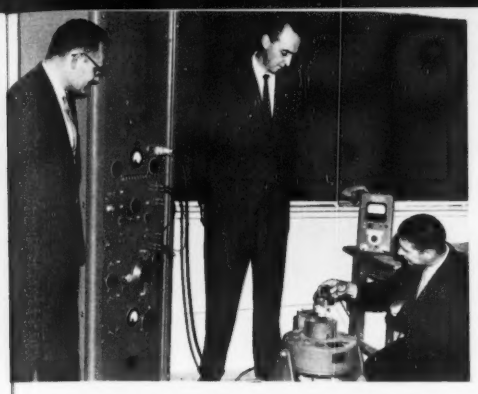
The Handbook covers all areas of practical astronautical engineering such as trajectories and flight performance; guidance, control, and instrumentation; chemical, nuclear, and electric propulsion systems; vehicle design and integration; crew engineering and manned space flight; systems engineering and management as well as operations and economy. The book is broken down into six parts: Part I—Fundamentals of Astronautical Engineering; Part II—Astrodynamics; Part III—Astrionics; Part IV — Propulsion Systems; Part V—Space Vehicles; Part VI —Space Flight Operations.

EDUCATION

VIBRATION TEST SYSTEMS

Yale University, the University of Southern California and The Polytechnic Institute of Brooklyn have been given vibration tests systems by MB for use in undergraduate and graduate vibration study programs.

The post war growth of environmental testing as a major research and development tool has generated increased emphasis on the subject in college engineering programs, according to Charles D. Brown, MB president. The availability of operating vibration test equipment in college labs will greatly facilitate effective environmental engi-



The University of Southern California's vibration test system shown here is one of three donated by MB Electronics.

neering education.

"The task of developing environmental engineers was assumed initially by industry," according to Mr. Brown. "The increasing academic emphasis in engineering colleges on vibration testing and other facets of environmental testing," he said, "has added new depth to current programs and has created a solid foundation for more and better education in the field."

LECTURE SERIES

The third series of Environmental Lectures sponsored by the I.E.S. **New York Metropolitan Chapter** will commence on Tuesday evening, Oct. 3, at New York University, University Heights, N.Y. The new series stresses the subjects of Shock, Vibration and Acoustic Noise.

For this series **Jesse Markson,** has enlisted an outstanding group of engineers. The Lecture Series will be held from 7 to 9 P.M. on consecutive Tuesdays (except Election Day) starting October 3rd. The registration fee is $25 and the Lecture Notes will cost $6 (no charge for Lecture Notes to IES members). Following is a list of topics and lecturers in the planned sequence of presentation.

"Designing for Shock & Vibration"
H. Forkois—U.S. Naval Research Lab.

"Modifying Environment by Use of Shock & Vibration Isolators"
Jesse Markson—E.R.A. Inc.

"Instrumentation for Dynamic Measurements"
Irwin Vigness—U.S. Naval Research Lab.

"Sinusoidal Vibration"
Karl Unholtz—Unholtz-Dickie Corp.

"Design of Fixtures for Shock & Vibration"
James Scott—Bell Telephone Labs.

"Random Vibration"
Robert Mains—General Electric Co.

"Shock Tests & Shock Spectra"
R. Cavanaugh—Barry Cotnrols Div.

"Damped Structures"
G. Ruzicka—Barry Controls Div.

"Laboratory Simulation of Actual Conditions"
Donald Williams—Sandia Corporation

"Acoustic Noise"
N. Doelling—Bolt Beranek & Newman Inc.

ENVIRONMENTAL SERIES

The first of a course of sixteen lectures on Environmental Engineering presented by the University of California Extension Division with the sponsorship of the Northern California Chapter of the I.E.S. took place at Palo Alto on September 6th and at Sacramento on September 7. Leslie W. Ball of the Boeing Company, Seattle, opened the series at the two locations with the subject "The Role of Reliability in Environmental Testing."

Interest in the lecture series is reflected by the response in terms of attendance figures. Over 170 registrants are reported for the series held at Palo Alto, and the Sacramento series with 115 registrants was a capacity sell-out one month in advance. Mr. Ball's presentation covered the many facets of reliability testing and featured an analysis of the changes in the buyer-seller relationship based on the increasing demand for reliability.

An information display illustrating the publications of the I.E.S. and indicating the advantages of and requirements for membership in the Institute will be a feature every week at each of the meeting places.

FACILITIES

BLAST SHOCK TEST

A new type of blast shock test machine has been developed by Wyle Laboratories to perform testing of Titan II hard site ground support equipment, and is now in operation at Wyle-El Segundo.

An actual hard site GSE isolated platform is simulated by the machine. Designed to provide shock forces simultaneously in both horizontal and vertical axes, the machine is designed to test specimens weighing up to 6,300 pounds.

The steel frame platform is approximately 80 x 100 inches, and is suspended by four rods pin-ended at both ends, permitting pendulum motion of the platform. In turn, the rods are supported by coil springs so that deflection either above or below the spring center position results in compressive loading of the springs. The entire moving system is suspended from a steel framework secured firmly to a concrete foundation.

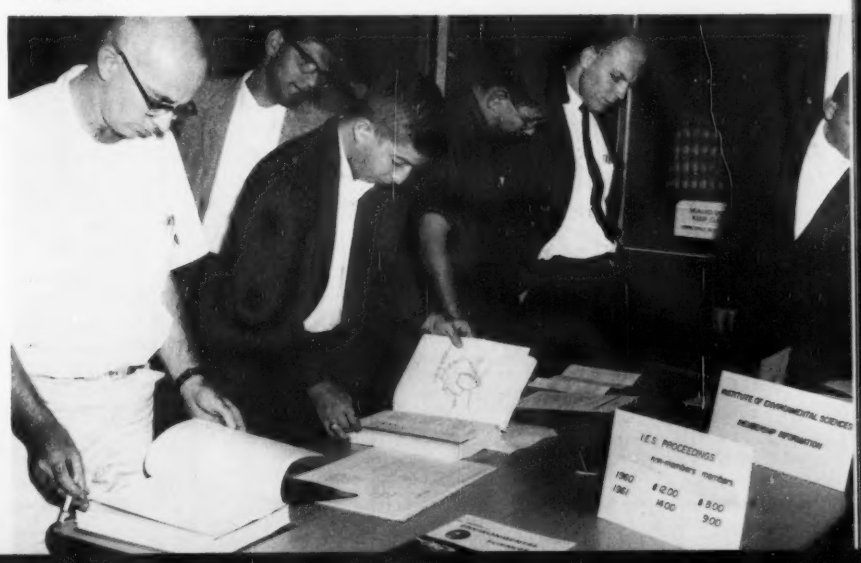
MEMBER'S NEWS

William Vandal was one of five Aeronutronic employes who received awards for special recognition of personal services to their communities. The selections were made by a judging committee of prominent local-area citizens.

Mr. Vandal received his award for the following activities: member of Tustin Chamber of Commerce, Columbus School PTA in Tustin, and the Santa Ana-Tustin Community Chest.

He has also been Scoutmaster of Boy Scout Troop 235 in Tustin. Vandal him-

Membership information booth at the University of California Lecture Series. ***See page 24.***



WILLIAM VANDAL

self has been elected to the "Order of the Arrow," a special honor fraternity within Scouting.

He has also taken an active part in the advancement of the professional field of environmental sciences through lectures and discussions in the University Extension program. He is a past national president of the Institute of Environmental Sciences.

Jerry P. Rosenblatt has been appointed to a staff position in the Environmental Engineering Division of the Bethlehem Corporation.

A native of New York City, Rosenblatt received his bachelor's degree in mechanical engineering from Rensselaer Polytechnic Institute. He recently completed the academic requirements for a master's degree in business administration at the Bernard Baruch School of the College of the City of New York.

JERRY P. ROSENBLATT

NEW PRODUCTS

HORIZONTAL VIBRATION TEST FIXTURES

A new series of horizontal vibration test fixtures redesigned to increase maximum usable frequency by 60 per cent has been announced by MB Electronics, New Haven, A Division of Textron Electronics, Inc.

The new test fixture, designated the Vibraplane, is available in four models with table dimensions of 20 x 20, 30 x 30, 40 x 40 and 48 x 48 inches. Through table redesign, the maximum usable frequency for the 20 x 20-inch model has been increased from 1200 to 2000 cps for large specimens. Smaller specimens can be tested to higher frequencies. Similar usable frequency increases have been achieved in the larger fixture models.

The Vibraplane consists of a magnesium specimen table which slides on a polished granite block. Sliding friction is reduced by an oil-air film. The table is driven by a standard vibration exciter rotated 90 degrees from vertical to provide driving force in the horizontal plane. A new attachment designed as an integral part of the Vibraplane table has simplified the table-exciter connection. Bolts are used to attach the test specimen to the table.

For more information, write MB Electronics, 781 Whalley Avenue, New Haven, Conn.

TEMPERATURE-HUMIDITY CHAMBER

A major breakthrough in the design of environmental test chambers has been achieved by Associated Testing Laboratories, Inc., Wayne, N.J., with the introduction of a temperature-humidity test chamber that has no mechanical refrigeration system either for low temperature or dehumidity conditions.

Priced at $2,675 F.O.B. Wayne, N.J., with immediate delivery, the Econ-O-Line Low-High Temperature Humidity Chamber (Model ELHH-4-LC) has internal working dimensions of 18″ by 18″ by 18″ and contains no mechanical components to break down, leak or cause problems.

The test chamber utilizes liquid CO_2

Continued on page 24

Continued

VIBRATION TESTING

ing of waivers on testing for parts which are "similar" to some which have passed in testing, it begins to seem that searching, even under the street lamp, is being abandoned.

When the problems discussed above became clearly formed a few years ago, we began to investigate means for "reading the output." Of all the techniques surveyed, X-ray seemed to hold the most promise. A modest X-ray source was obtained and work was begun on Cine-Radiography techniques. From the outset, the work was encouraging, although limitations in the state of the X-ray art have been a constant problem. The fact is, however, that Cine-Radiography *did* expose, and, thereby, aid in solving, a number of dynamic problems which could *not* have been foreseen or "sleuthed" from outside the package. Work goes on, now with the hope of achieving a measuring device which will "read the output" at any point of inetrest within the package. There are, of course, limitations to the thicknesses and densities of materials through which an X-ray system can visualize. However, precisely those requirements which make a package fit for airborne use, i.e., the use of thin-walled, low density materials, make the package susceptible to X-ray investigation. In this instance nature is not perverse! !

This is not to suggest that the X-ray technique is the only way or the best way. It is, rather, to give an example and to encourage further investigation into any technique which will gather the information required to make a truly useful tool of vibration testing.

To those who have struggled with vibration problems against all the odds enumerated above, the cine-radiographic approach is offered as evidence that, given work, these problems can be solved.

PRECISION SCIENTIFIC OFFERS A COMPLETE *Freas* LINE

OVER HALF CENTURY OF KNOW-HOW IN CONSTANT TEMPERATURE EQUIPMENT

The only constant temperature cabinets where temperature uniformity is guaranteed

FREAS MECHANICAL CONVECTION OVENS

FLOOR MODEL
3 sizes—6 models
3 to 10 cubic ft. capacity

TABLE MODEL
3 sizes—6 models
1.3 to 10 cu. ft. capacity

Freas provides the answer to every constant temperature laboratory need. Every cabinet is meticulously crafted for maximum accuracy . . . durability . . . convenience. Lifetime "black-heat" heater banks provide a new standard in maximum temperature . . . 325°C., controlled by an instantaneous electronic thermostat. Operation is simple and fast. Dial is calibrated in centigrade and fahrenheit . . . no guesswork . . . no reference numbers . . . no experimenting. All results 100% reproducible. Direct drive balanced turboblower system changes air in chamber as often as 3 times per minute . . . increases loading capacity . . . more work loads per day . . . improved uniformity to ±2.0°C. at 325°C. (certified with 12 thermocouples). Stainless steel interiors, including air ducts.

FREAS GRAVITY CONVECTION OVENS

Same quality . . . same superb craftsmanship as mechanical convection models . . . less blower system. New unique diffuser walls provide positive air flow throughout entire working chamber. Ideal for drying fine powders and other uses where a gentle movement of air is desired. Temperature range is to 325°C. with electrically controlled uniformity to ±1.8°C. at 100°C. New work load capabilities plus a selection of sizes and models to meet all your laboratory needs.

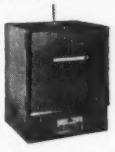


TABLE MODEL
4 sizes—8 models
1.3 to 10 cu. ft. capacity

FREAS VACUUM OVENS

Everything you want in a vacuum oven . . . big 1½ cubic feet capacity . . . 408 sq. inches of usable shelf area . . . heat range to 225°C. . . . uniformity to ±2.4°C. at maximum temperature . . . operating convenience . . . absolute safety. Cast aluminum vacuum chamber with "O" ring door seal withstands pressures to 2 psi. . . . has inert gas inlet port and provision for access ports. Ideal for semi-conductor testing . . . impregnation, simulated high altitude studies, and anaerobic incubations.

Freas — The safest, most convenient and most dependable constant temperature equipment is actually the **least expensive** . . . based on the lifetime of trouble-free performance you will enjoy.

A complete line . . . featuring cabinets for every requirement . . . cabinets engineered for constant temperature control and uniformity with the advanced styling . . . greater range . . . ease of operation . . . unequalled performance you'll only find in the leader . . . Freas. Sold by the leading Laboratory Supply Distributors.

All the details are in our big 32 page Freas Bulletin . . . send for it today.

OTHER SPECIAL PURPOSE FREAS CABINETS INCLUDE:

- **Hi-Temp Ovens**
- **Humidity Cabinets**
- **Conditioning Ovens**
- **Revolving Shelf Oven**

Since 1920 PRECISION SCIENTIFIC CO. PS

WEST CORTLAND STREET • CHICAGO 47, ILLINOIS
LOCAL OFFICES IN: CHICAGO • CLEVELAND
HOUSTON • NEW YORK • PHILADELPHIA • SAN FRANCISCO

FREAS LOW TEMPERATURE INCUBATOR

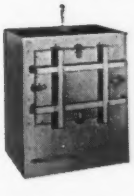
Precisely controlled heating and cooling from this one versatile 11 cubic feet capacity cabinet with 7.5 square feet of adjustable shelf area . . . plus door storage. Temperature range from 5°C. to 50°C. with uniformity to ±0.6°C. External controls permit reading and adjusting without disturbing test conditions. Perfect for BOD tests, genetics research, complement fixation and enzyme tests, serum studies, preservation and conditioning of medications and storage of heat and light sensitive incubations. All welded steel cabinet with baked white porcelain enamel finish. Attractive easy to clean plastic interior. Five year guarantee on compressor and control system . . . Local service available if ever necessary.

FREAS INCUBATORS

The performance . . . convenience . . . years of service built into every Freas incubator are unequalled in the industry. Unique diffuser wall system does away with stagnant air pockets . . . insures positive results . . . 100% repeatable. Temperature uniformity, the acid test of performance, is held to a precise ±0.25°C. at 37°C. Double seal window in door allows test observations. Entire interior, including ducts is stainless steel for easy cleaning. Temperature range is from 35°C. to 70°C. With solid door if desired.

INCUBATORS
4 sizes—8 models

FREAS BLOWOUT PANEL SAFETY OVENS



BLOWOUT PANEL SAFETY OVEN
8 new models—Mechanical or Gravity Convection

If there is a possibility, even remote, of a pressure build-up or explosion . . . you'll enjoy the security of a Freas Blowout Panel Safety Oven. A snug fitting blowout panel is attached with special catches to the rear of the oven. If explosive pressures build up, the panel simply pops into a securely bolted cage . . . no danger to worker or surroundings. Panel is easily and quickly reset for continued operation.

Available in gravity and mechanical convection models with all the standard Freas performance features.

FREAS HAZARD-SAFE OVENS

The handling of hazardous materials and atmospheres is made safely routine, by use of Freas Hazard-Safe Ovens. Every possible safety feature is employed to bring you carefree operation to 260°C., with stand out uniformity of ±1.6°C. in mechanical convection models and ±3.0° C. in gravity convection models. All switches, wiring and motors are explosion-proof . . . pressure release safety door latches . . . safety inter-lock to shut off heaters and motor if door is opened . . . hi-limit control to take over if thermostat should fail . . . everything for real hazard-safe duty . . . plus the exclusive Freas performance features.

Steam heated Explosion Proof Ovens . . . the only cabinets listed by Underwriters' Laboratories for operation in Class 1, Group C and D Hazardous Atmospheres are also available in 6 space saving floor models. Temperature range is from 40°C. to 150°C.

HAZARD-SAFE OVENS
8 Advanced Style Models

1962 TECHNICAL MEETING COMMITTEE MEMBERS

These are the committees which will plan and conduct our 1962 Technical Meeting and Equipment Exposition. The Meeting will be held in Chicago at the Sheraton (Towers) Chicago Hotel on April 11, 12 and 13, 1962.

EXHIBITS COMMITTEE

CHAIRMAN
Norman Ponge
Space Tronics

FISCAL COMMITTEE

CHAIRMAN
William J. Carey
Murphy & Miller Co.

PUBLICITY COMMITTEE

CHAIRMAN
Neal Granick
NASA, Goddard Space Flight Center

OUTSIDE ACTIVITIES COMMITTEE

Robert Jones
Admiral Corp.

Mrs. Lillian Neukuckatz

Mrs. Betty Murphy

Mrs. Arlyss Karlson

CHAIRMAN
Robert L. Karlson
Endevco Corp.

REGISTRATION COMMITTEE

Cliff Shoemaker
Lear Inc.

Matt Schmitt
Lear Inc.

Mrs. Phyllis Monroe

Mrs. Maxine Shoemaker

Mrs. Meredith Schmitt

CHAIRMAN
J. P. Monroe
Lear Inc.

FACILITIES COMMITTEE

CHAIRMAN
William F. Wilde
Blue M Electric

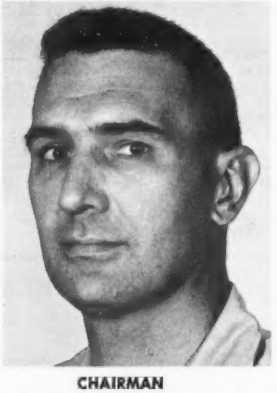
PUBLICATIONS COMMITTEE

CHAIRMAN
Don W. Hoeck
Automatic Electric Co.

GENERAL CHAIRMAN

DONALD J. FOX
Fenwal Inc.

TECHNICAL PROGRAM COMMITTEE



CHAIRMAN
Frank Merry
White Sands Missile Range

Al Neukuckatz
Inland Testing Labs

Robert Joel
Hermes Electronics Co.

David Askin
Frankford Arsenal

Bill Gardner
Sandia Corp.

Cornell Stradling
Kearfott Co.

J. M. Christensen
W.A.D.D. Aerospace Medical Laboratory

Francis J. Clauss
Lockheed Missiles and Space Division

NEW! HIGH CAPACITY!

TWO-STAGE WELCH "DUO-SEAL" VACUUM PUMP No. 1398

50 CFM (1400 LITERS/MINUTE)

1 x 10⁻⁴ mm Hg (0.1 MICRONS)

THE YOUNGEST, BUT LARGEST MEMBER of the Welch family of "Duo-Seal" oil sealed rotary vacuum pumps makes its appearance as the No. 1398. This new pump offers very high capacity and excellent ultimate vacuum characteristics with no sacrifice of long life, low maintenance, freedom from vibration and minimum noise level. These features have long made Welch "Duo-Seal" pumps the most widely used of all rotary vacuum pumps.

1398's, like all Welch "Duo-Seal" Pumps, are thoroughly run-in at the factory and tested until they exceed their vacuum guarantee.

The new 1398 is highly recommended for all industrial and laboratory applications requiring high pumping capacities and low pressures. Typical uses are electron tube evacuation, vacuum distillation, dehydration, reduction, sublimation, metallizing, metal processing, leak detection, hermetic sealing and back-filling, impregnation and general scientific studies.

IMPORTANT FEATURES:

- High pumping speed — 50 CFM (1400 liters/minute)
- Low ultimate pressure — 1 x 10⁻⁴ mm Hg (McLeod)
- Quiet, vibration-free operation
- Compact, rugged design
- Air-cooled
- Vented Exhaust Valve
- Flanged, O-Ring-Sealed Intake Port
- Totally Enclosed Belt Guard
- Air Intake Screen
- Exhaust Filter
- Trouble-free, low maintenance

WELCH "DUO-SEAL" PUMPS ARE CARRIED IN STOCK BY AUTHORIZED DEALERS.

Welch Duo-Seal Vacuum Pumps are manufactured in wide variety of capacities and ultimate vacuum characteristics. They range in capacities from 21 to 1400 liters/minute and ultimates from 2 x 10⁻² mm Hg down to 1 x 10⁻⁴ mm Hg.

WRITE FOR DUO-SEAL CATALOG and BULLETIN 1398 for full description and prices.

SINCE 1880 THE WELCH SCIENTIFIC CO.

foremost manufacturers of scientific equipment

1513 N. Sedgwick St. • Chicago 10, Ill.

Continued

DISTURBING FORCES

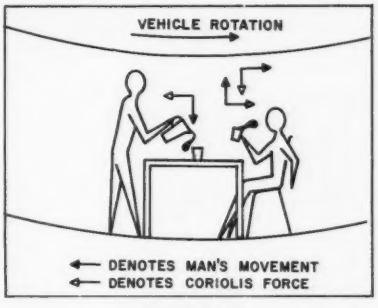


FIGURE 5

moves *with* the vehicle rotation, the vehicle rotation, the Coriolis force is additive to the local weight of the object and will act in a downward direction.

Not only will Coriolis forces adversely affect the movement of human beings in a rotating space vehicle, but inanimate objects will also be affected. Figure 5 illustrates some effects.

In conclusion, it can be stated that careful consideration must be given to the positioning of functional machinery, as the operation of this machinery, especially delicate mechanisms, may be seriously disturbed by the effects of Coriolis forces. The same careful consideration must be given to the positioning of controls and control consoles in order that the human operators will not be unnecessarily exposed to the perturbations of Coriolis forces which may effect task performance, particularly emergency control movements.

Summing up, then, the following design dictates can be given:

(a) The optimum vehicle radius at floor level should be from 45 to 50 feet.

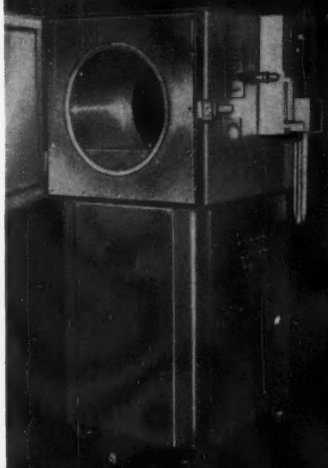
(b) Smaller radii should be avoided because of increasingly intolerable Coriolis components and gravity gradients.

(c) Gravity levels of 0.10g will require large spin radii to overcome perturbing Coriolis forces. Such radii have already been proposed for nuclear powered vehicles which have the nuclear power plant separated from the manned compartment by a mile of cable.

BETHLEHEM'S ValuLine Economy Series offers first small true-combined temp.-alt. simulator

ValuStrat

available with your choice of instrumentation



interior dimensions:
- 15″ high
- 17″ averaged width
- 18″ deep

FAST DELIVERY

Write for Bethlehem's complete Environmental Product Catalog.

ENVIRONMENTAL ENGINEERING DIVISION

THE BETHLEHEM CORPORATION EST. 1856

225 W. SECOND ST., BETHLEHEM, PA.

OTHER BETHLEHEM DIVISIONS: SPECIAL CONTRACTS, BETHLEHEM FOUNDRY & MACHINE, PROCESS EQUIPMENT, CEMENT MACHINERY, DYNATHERM OIL HEATING.

ANNUAL AUDITOR'S REPORT

BY-LAWS OF THE INSTITUTE OF ENVIRONMENTAL SCIENCES, ARTICLE VI, THE EXECUTIVE COMMITTEE, SECTION B., POWERS AND DUTIES, THE EXECUTIVE COMMITTEE SHALL BE CHARGED WITH THE DIRECTION AND MANAGEMENT OF THE AFFAIRS OF THE INSTITUTE AND SHALL INCLUDE THE FOLLOWING DUTY, CAUSE THE BOOKS AND ACCOUNTS OF THE INSTITUTE TO BE AUDITED ANNUALLY BY A CERTIFIED PUBLIC ACCOUNTANT AND MAKE THE REPORT OF SAID AUDIT AVAILABLE TO THE INSTITUTE MEMBERS.

AUDITS - INCOME TAXES
INVESTIGATIONS - SYSTEMS
ILLINOIS SOCIETY OF CERTIFIED PUBLIC ACCOUNTANTS
PHILIP C. CORRADO
PHILIP C. CORRADO, JR

PHILIP C. CORRADO & Co.
CERTIFIED PUBLIC ACCOUNTANTS
77 W. WASHINGTON STREET
CHICAGO 2

TELEPHONE
CENTRAL 6-0863

August 21, 1961

To the Executive Committee
Institute of Environmental Sciences
Post Office Box 191
Mount Prospect, Illinois

Gentlemen:

We have examined the balance sheet of the INSTITUTE OF ENVIRONMENTAL SCIENCES (a non-profit organization) as of June 30, 1961 and the related statement of income and expense for the fiscal year then ended. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests and such other auditing procedures as we considered necessary in the circumstances.

The balance sheet and statement of income and expenses are presented on a modified accrual basis, under which membership dues are reported on a cash basis.

In our opinion, the accompanying balance sheet and statement of income and expense present fairly the financial position of the Institute of Environmental Sciences at June 30, 1961 and the results of its operations for the fiscal year then ended in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Respectfully submitted,

PHILIP C. CORRADO & CO.

Certified Public Accountants

EXHIBIT A

INSTITUTE OF ENVIRONMENTAL SCIENCES

BALANCE SHEET - JUNE 30, 1961
(Modified Accrual Basis)

ASSETS

Current assets:		
Cash in bank and on hand	$ 10,009.42	
Accounts receivable (Note 1)	2,729.80	
Inventory of proceedings books - at cost	7,785.32	
Total current assets		$ 20,524.54
Fixed assets:		
Equipment (cost less depreciation)		396.75
Total assets		$ 20,921.29

LIABILITIES AND NET WORTH

Current liabilities:		
Accounts payable	$ 64.96	
Due to local chapters	1,473.00	
Withholding and payroll taxes	444.95	
Total current liabilities		$ 1,982.91
Net worth:		
Balance - June 30, 1960	17,008.12	
Net income for the fiscal year ended June 30, 1961 (per Exhibit B)	1,930.26	
Balance - June 30, 1961		18,938.38
Total liabilities and net worth		$ 20,921.29

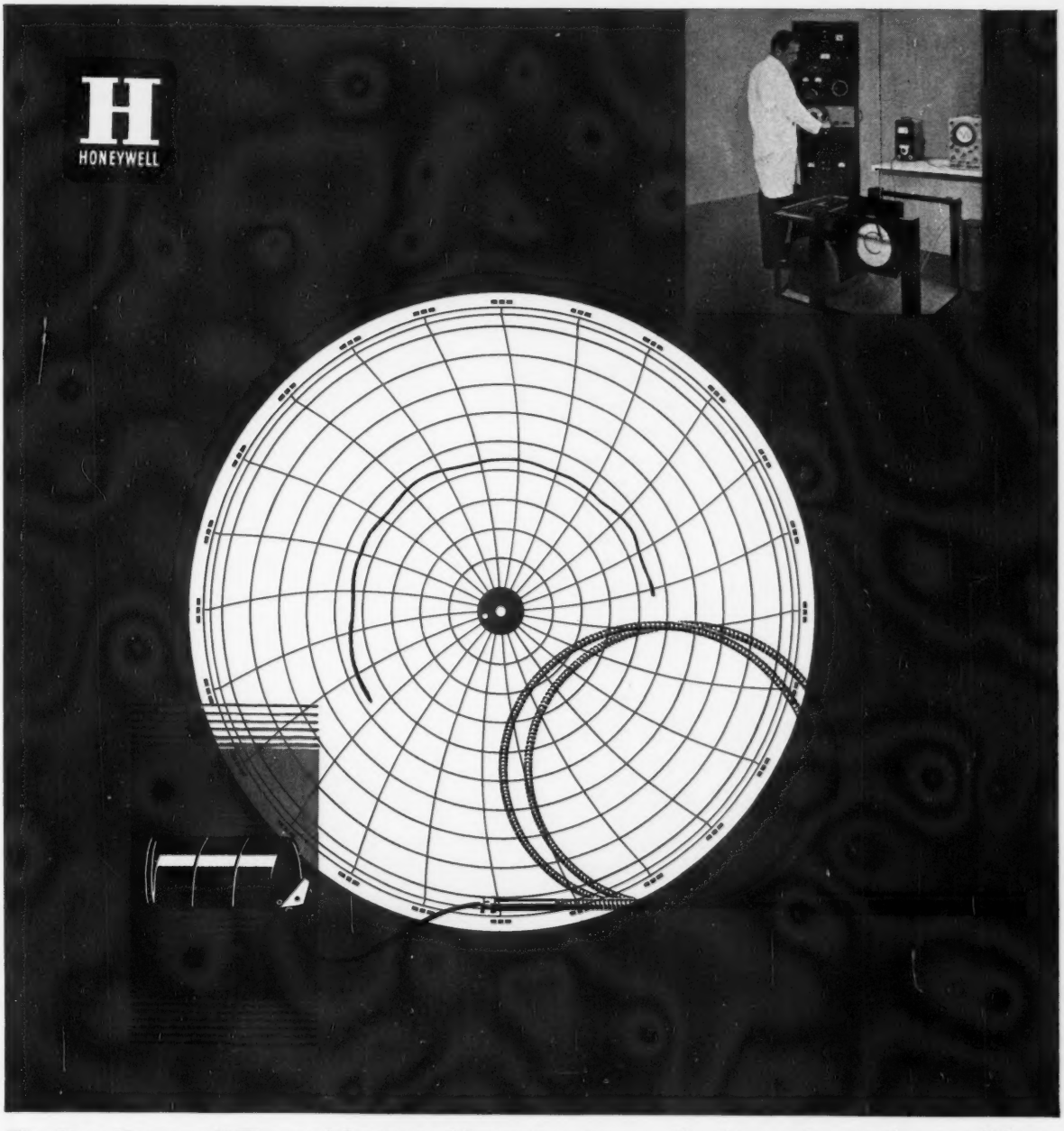
Note 1: Membership dues are reported on a cash basis.

EXHIBIT B

INSTITUTE OF ENVIRONMENTAL SCIENCES

STATEMENT OF INCOME AND EXPENSE
FOR THE FISCAL YEAR ENDED JUNE 30, 1961
(Modified Accrual Basis)

Income:		
Membership dues - cash basis - net		$ 10,489.50
Sale of Proceeding Books		5,807.33
Meeting receipts		32,399.02
Journal publication		1,727.27
Total income		50,423.12
Less: Operating expenses:		
Membership expense	15,646.17	
Proceeding expense	3,792.84	
1961 Meeting expense	25,279.08	
Journal publication	3,774.77	
Total operating expense		48,492.86
Net income (to Exhibit A)		$ 1,930.26



The New Honeywell Thermal System withstands extreme vibration and corrosion conditions

Here's a new gas-actuated thermal system that takes the zig-and-zag out of temperature recording under severe vibration conditions.

A complete series of vibration tests has proved the vibration resistance of the new Class III thermal system. In these tests (shown above), the Class III system was installed in a standard Honeywell rectangular case recorder, and subjected to forced vibrations in three mutually perpendicular planes. With accelerations up to 0.2G from 0 to 200 cps, maximum pen oscillation was limited to 1.5%. For more than 75% of the range, pen oscillation was less than 0.5%, with no resonant effects at 60 cycles.

Get the complete story by contacting your nearby Honeywell field engineer. Minneapolis-Honeywell, Wayne and Windrim Aves., Phila. 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ont.

Honeywell

First in Control

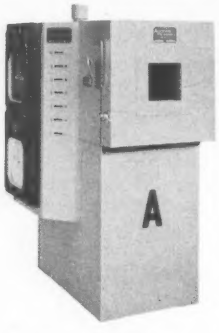
SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Continued

ENVIRONEWS

refrigeration to pull temperature down as far as minus 100 degrees Fahrenheit and to control humidity in the 20 to 95 per cent RH range. The chamber's high temperature range is plus



350 degrees Fahrenheit.

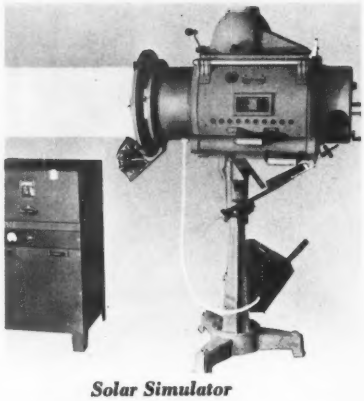
As standard equipment, the chamber is furnished with a 2 Pen-2 Cam Programming Recording Conrtoller for complete documentation of its performance.

TEMPERATURE-HUMIDITY TEST UNIT

A new temperature-humidity environmental test unit providing the relatively large test space of 5.1 cubic feet in a compact cabinet, has been added to the standard line of Tenney Engineering, Inc. The new unit (the Tenney-Mite TH), Model TMTH0200, is designed for MIL-E-5272C, MIL-STD-202B and MIL-STD-170 testing. It provides temperatures from 0° to +200°F and relative humidity from 20% to 95% in the dry bulb range, limited only by +35° to +185° dew point.

Further information can be obtained from Tenney Engineering, Inc., 1090 Springfield Road, Union, New Jersey.

Tenney Test Unit



Solar Simulator

SOLAR RADIATION SIMULATOR

Genarco Inc., 97-04 Sutphin Blvd., Jamaica, N. Y. describes a new Solar Radiation Simulator in its pamphlet #310. It is used to test space vehicles or other components in the radiation conditions of outer atmosphere. The simulator produces a beam of collimated radiation with the same spectrum, intensity and divergence as the sun. The model shown here produces a beam of radiation 12″ in diameter.

PUBLICATIONS

LABLINE CATALOG

The complete line of scientific instruments, apparatus and equipment, manufactured by Labline, Inc., Chicago and its subsidiaries, has been incorporated into a new illustrated catalog available to all scientific and purchasing department personnel.

Contained within its 200 plastic bound pages are many products being shown for the first time. Included are instruments for clinical, medical, chemical, bio-chemical, petro-chemical, research, physical testing and industrial control laboratories.

Free catalog copies are available by writing directly to Labline, Inc., 3070 W. Grand Ave., Chicago 22, Illinois.

PHYSIOLOGICAL PERFORMANCE CHARTS

The environmental conditions man is able to tolerate while continuously living in a space vehicle have been charted by The Garrett Corporation's AiResearch Manufacturing Division of Los Angeles.

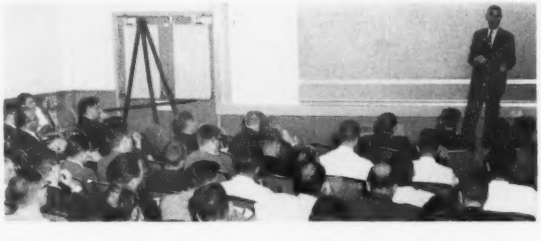
The information, presented in two graphs, reflects the latest results of tests and research in the environmental control field. One graph—an oxygen-pressure chart—shows the physiological effects of oxygen in the atmosphere of a space vehicle and the total pressure of that atmosphere. The other—a temperature-humidity chart—presents the physiological effects of dry bulb temperature and the humidity of the atmosphere in a space vehicle.

The Physiological Performance charts were developed by Frederick H. Green, AiResearch assistant chief of preliminary design, in cooperation with Dr. James Waggoner, Garrett's aerospace medical director, and Dr. Ulrich Luft, Lovelace Foundation.

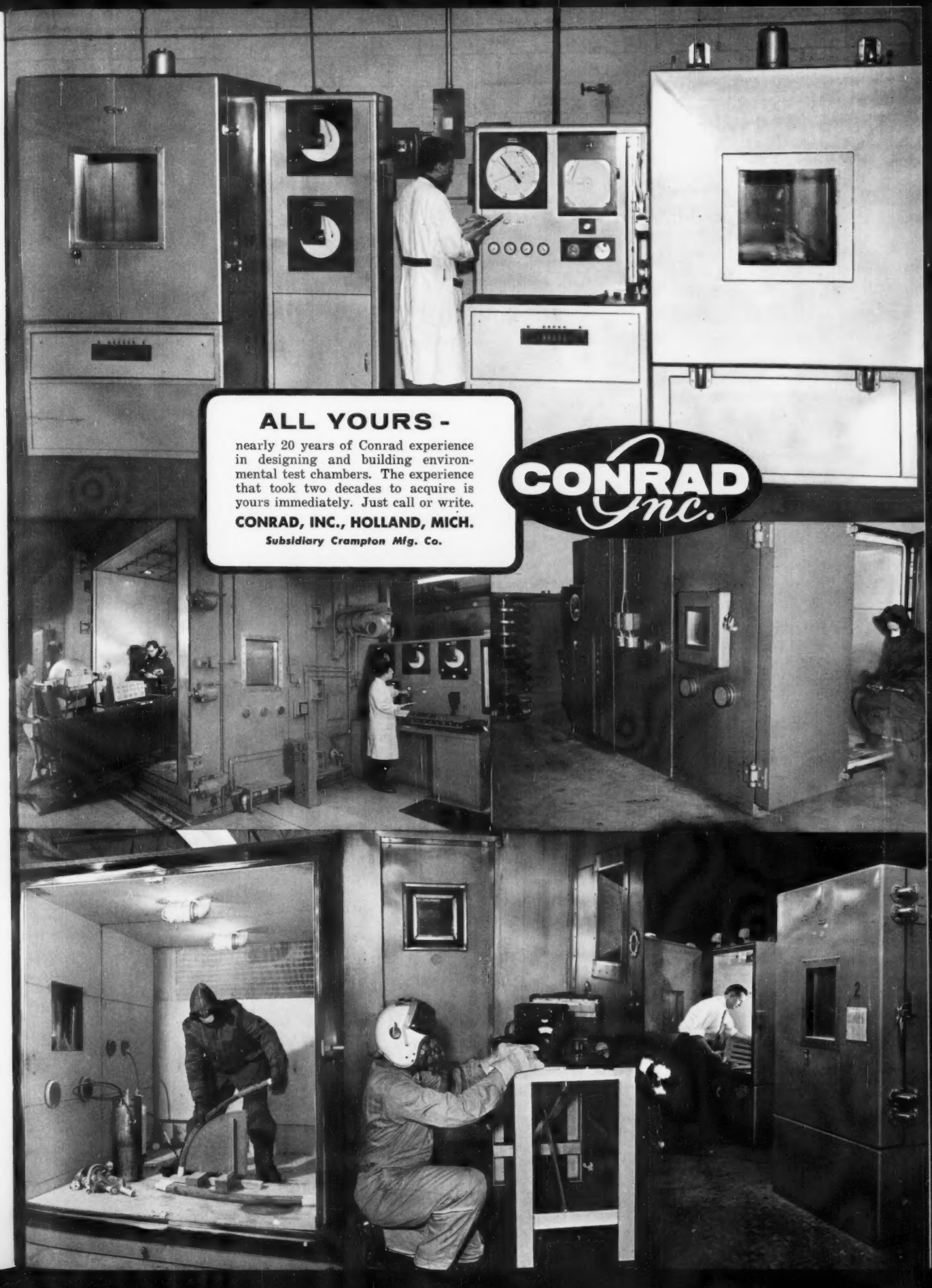
Anyone interested in obtaining a copy of the charts may write The Garrett Corporation, 9851 Sepulveda Boulevard, Los Angeles 45, California.

Continued on page 26

About the Cover



Dr. Leslie W. Ball was the first lecturer for the University of California Lecture Series as sponsored by the Northern California Chapter of the Institute of Environmental Sciences. Dr. Ball's subjects included: Relation of environmental testing and the reliability program. The purpose and function of a reliability effort. Reliability tests with their functions and requirements. Reliability demonstrations under operational conditions. Examples of environmental and reliability tests. Reliability terms and confidence factors. See page 17.


ALL YOURS -
nearly 20 years of Conrad experience in designing and building environmental test chambers. The experience that took two decades to acquire is yours immediately. Just call or write.
CONRAD, INC., HOLLAND, MICH.
Subsidiary Crampton Mfg. Co.
CONRAD Inc.

Continued

WATER

were determined. The temperature difference varied approximately exponentially with depth, and the temperature gradient was such that the side-view image showed about an 8-mm thickness of surface film affected at the time that plunging initiated. The image further showed this film to be immediately reduced to a thickness of about 5 mm.

In theories predicting the onset of thermal convection, convective circulation starts when the numerical value of the Rayleigh number,[2] Ra, given by the dimensionless combination

$$\mathrm{Ra} = \frac{g a \beta h^4}{kv}$$

exceeds a particular value. In this expression, g is the acceleration of gravity, a is the coefficient of cubical expansion, β is the temperature gradient, h is the depth of the fluid, k is the thermal diffusivity, and v is the kinematic viscosity. Data from the present study showed that instability first occurs when Ra equals 1193 and the body of water is near room temperature. The data also indicated that the Ra value required to maintain convective circulation is about 9 percent of that required to initiate convective currents.

FIGURE 3

Part of the equipment used at the National Bureau of Standards to study the convective currents that are set up in water exposed to still air. Here W. R. Rowland measures the temperature in a tank of water (upper left). Photographs obtained with schlieren apparatus (not shown) are correlated with changes in temperature induced by evaporation.

REFERENCE

[2]On convection currents in a horizontal layer of fluid, when the higher temperature is on the under side, Lord Rayleigh, Phil. Mag. *32*, 529 (1916).

Continued

ENVIRONEWS

ENVIRONMENTAL EFFECTS ON MATERIALS AND EQUIPMENT

This publication is intended to serve those offices, laboratories, and personnel concerned with problems of the "induced" environments—designers, materials and test engineers, specification writers, research directors, and others responsible for operability, reliability, and durability of military or other materials and equipment.

The monthly service will provide at least forty substantive abstracts and forty or more key-word extracts (telegraphic abstracts) of current articles drawn from world scientific and technical literature in the induced environment specialties — shock, vibration, thermal factors, vacuum, gravity, magnetism, electromagnetic radiation, dissociated and ionized gases, meteoritic dust, auroras, and coronas.

The new journal will contain a monthly index but will be supplemented with an annual cumulative subject and author index.

Subscriptions at $25.00 per year are available through the Printing and Publishing Office, National Academy of Sciences, National Research Council, 2101 Constitution Avenue, N.W., Washington 25, D.C.

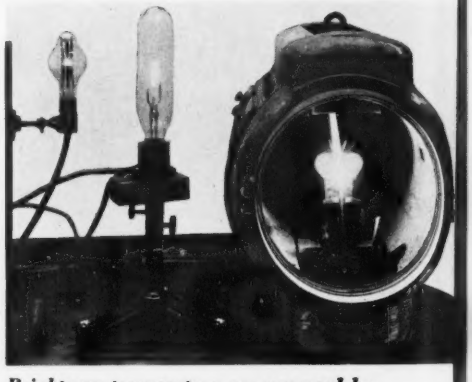
SERVICES

STANDARDS LABORATORY

North Hills Electronics has established a standards laboratory and is initiating a calibration service for industry. The facility has been set up at the North Hills plant in Glen Cove, L. I., N. Y. Being offered as a service in the measurement and calibration of D.C. voltage and current, as well as resistance. Primary voltage and resistance standards which have been certified by the National Bureau of Standards consist of banks of saturated standard cells certified to 0.001% and NBS type resistors kept in a precisely controlled temperature oil bath, whose temperature is maintained at 28° centigrade within one hundredth of a degree.

PYROMETER CALIBRATION

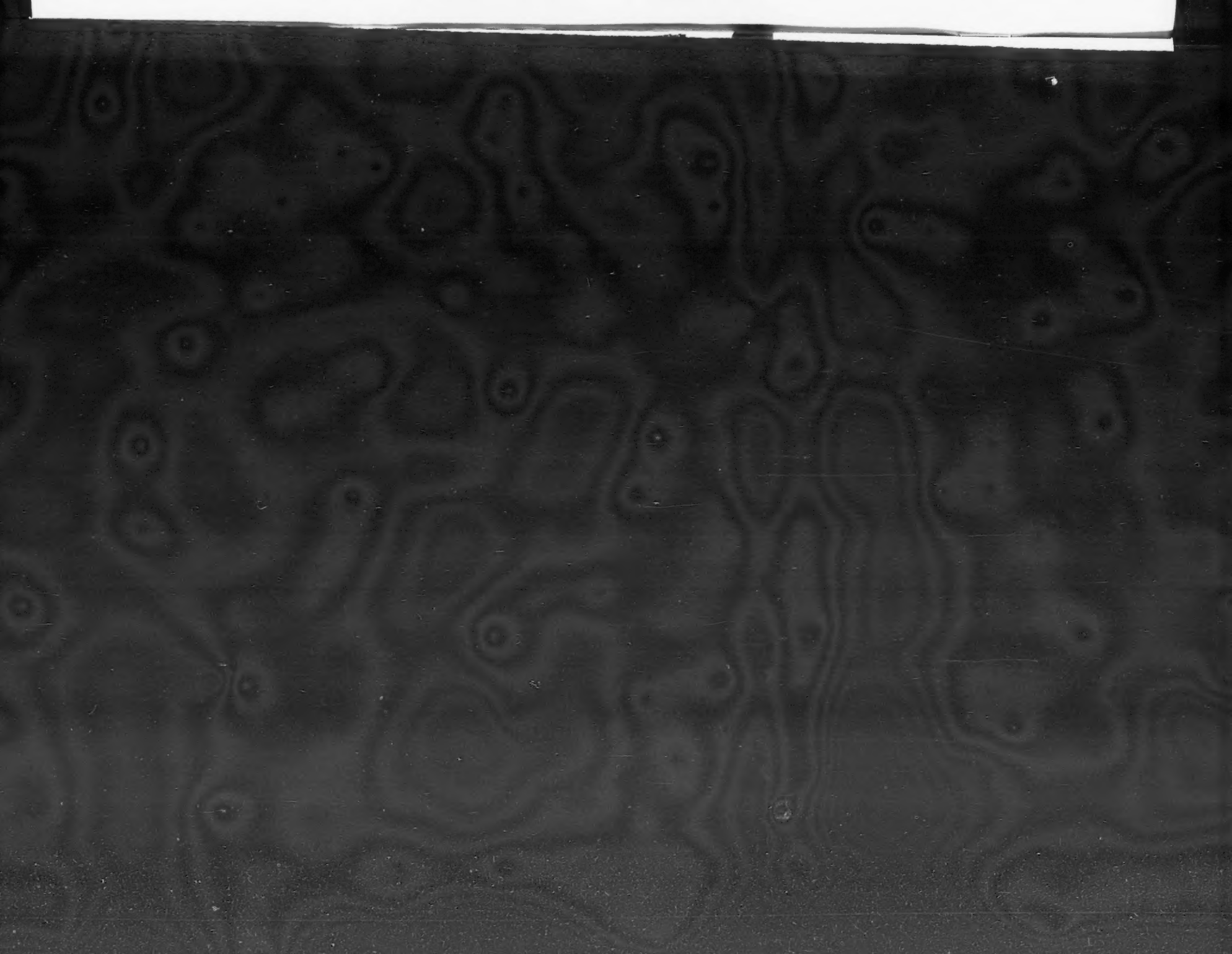
The National Bureau of Standards, as part of its program to insure accurate and uniform measurements, calibrates optical pyrometers for science and industry. The fee schedules are available from the Office of Technical Information, National Bureau of Standards,



Brightness temperature sources used by the National Bureau of Standards in the calibration of optical pyrometers. The brightness temperature of the zirconium arc (left) is fixed at about 2800°C, whereas that of the positive crater of the carbon arc (right) is about 3530°C. The brightness temperature of the strip lamp (center) is varied during calibration from 800 to 2400°C.

Washington 25, D. C.

The calibrations are performed over the temperature range of 800-4200°C. The uncertainty of the calibration varies from about 3 deg (at 1063°C) to 40 deg (at 4200°C). In addition, the Bureau calibrates tungsten strip lamps for use as sources of known brightness temperature over the range of an optical system.



dynamic instrumentation Σ

TELEMETRY SIGNAL CONDITIONING

Problem: Meeting the exacting and varied requirements imposed by environment, transducer, power source and SCO.

Solution: A multiple-option approach with features dependent upon the specific job. Options include: Filter, limiter, bias, super power regulator, transient suppression and calibration insertion with the unique Endevco "charge" amplifier.

MECHANICAL IMPEDANCE MEASUREMENTS

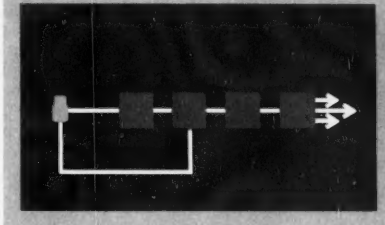
Problem: Accurate measurement of structural impedance without significantly affecting the dynamic characteristics of the structure.

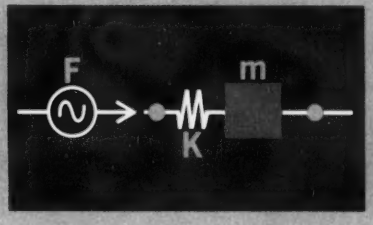
Solution: A very stiff and small combined force-accelerometer transducer incorporating the highly practical center-mounting configuration. The Endevco Model 2110 Impedance Head and Model 2953 Force Generator provide the ideal combination for accurate point measurement.

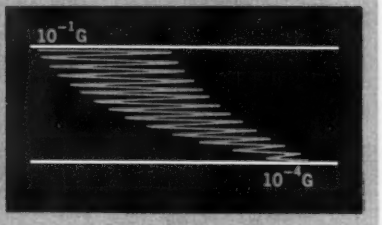
LOW G MEASUREMENTS

Problem: Broadband measurements of less than 0.0001 g with adequate signal-to-noise-ratio. The U.S. Navy "noise suppression" specification is one example [MIL-STD-740 (SHIPS)].

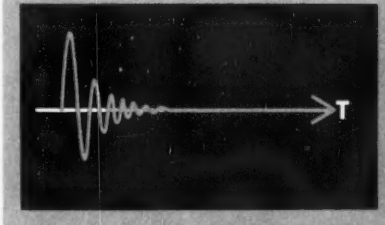
Solution: High output accelerometers, low noise battery operated preamplifiers, system protection against ground loop and stray field noise pickup. The Endevco 2870 and 2870M1 Systems provide these advantages.

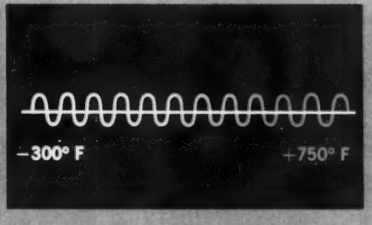


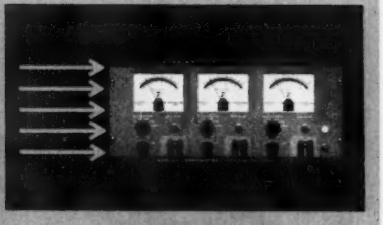




SIX DYNAMIC ANALYSIS PROBLEMS SOLVED







SHOCK AND IMPACT MEASUREMENTS

Problem: Ruggedness, high resonance frequency and low frequency response to measure transients whose amplitude and pulse widths cover a wide dynamic range.

Solution: Model 2225 Accelerometer with 80 Kcps resonance frequency. Preamplifiers with flat low frequency response below 2 cps, wide dynamic range, RC time constant adjustment.

EXTREME TEMPERATURE MEASUREMENTS

Problem: Measurements at cryogenic and/or elevated temperatures.

Solution: Model 2245 Accelerometer operates at −300° F to +750° F without artificial cooling. Water cooled accelerometers operate with mounting surface temperatures of 2200° F. Other accelerometer-amplifier systems incorporate built-in compensation for extreme temperature stability throughout designated ranges.

COMPLETE LABORATORY SYSTEMS

Problem: Monitoring and/or recording dynamic outputs at semi-remote locations from piezoelectric transducers.

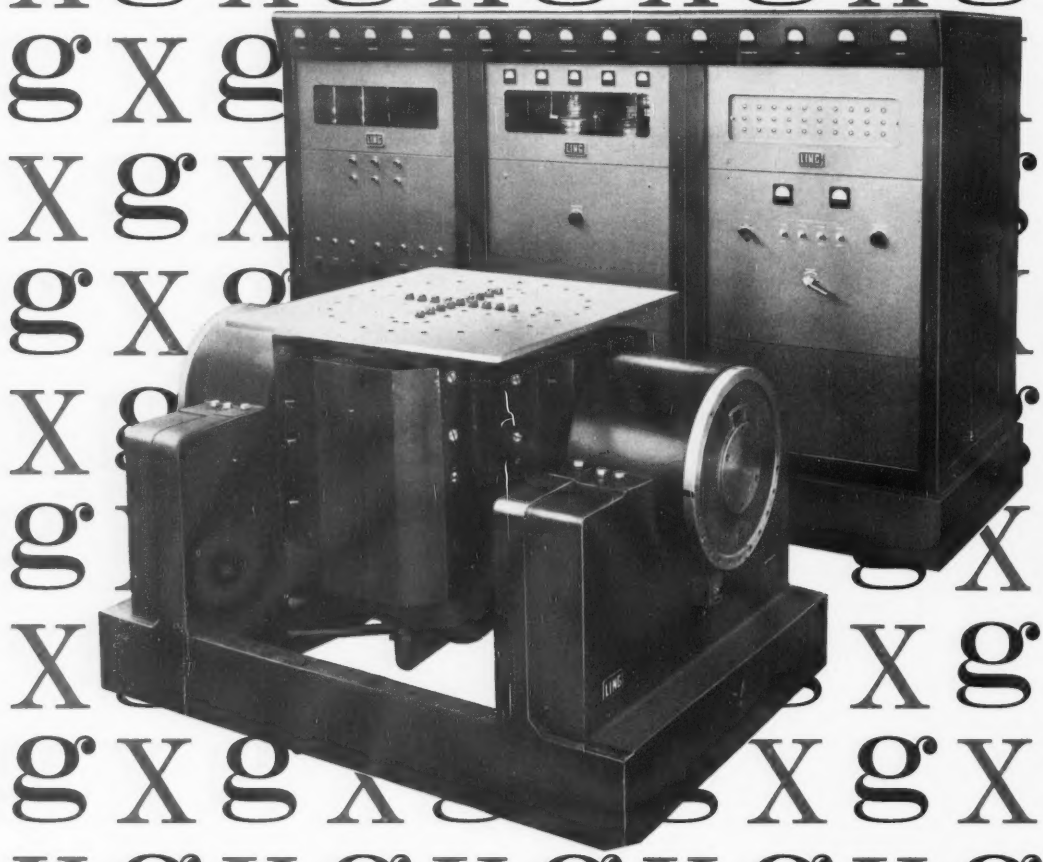
Solution: Endevco Model 2702B DYNAMONITOR®. One integrated system with simple calibration procedure, no capacitive signal attenuation and a built-in VTVM and galvanometer recorder amplifier.

For complete technical information about Endevco products write Department "D" or telephone SYcamore 5-0271.

TWX: 7764 CABLE: ENDEVCO PRINTED IN U.S.A.

® ENDEVCO CORPORATION 1961

ENDEVCO CORPORATION 161 EAST CALIFORNIA BOULEVARD • PASADENA • CALIFORNIA • SYCAMORE 5-0271



ONLY LING'S NEW X-ARMATURE SHAKER TAKES 100 pound packages to 100"g"... 250 pounds to 60"g"

Ling brings you another important development in vibration testing—the revolutionary L-200 Shaker with the capability needed to test heavier packages at higher "g" levels than ever before. The L-200, with a force rating of 22,000 pounds, is designed on a new Ling concept. The unique "X" design armature develops uniform force on two rows of mounting studs which are set in an "X" pattern on the big table. An exceptionally low stray field—less than 3 gauss at table level—protects sensitive guidance packages. The armature weight is only 115 pounds. This, plus efficient coupling, lets you take a 100-pound package up to 100 "g" or a 250-pound package to 60 "g"—a performance no other shaker can match. The L-200's interior is completely sealed off to screen out all chips, dust or contaminants, and is designed to allow environmental test adaptability. For more details on the advantages of the L-200, write to Department JES-1061 at the address below.

LTV

LING-TEMCO-VOUGHT, INC.

LING ELECTRONICS DIVISION

1515 SOUTH MANCHESTER, ANAHEIM, CALIFORNIA • PRospect 4-2900